THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE V. VOL. VI.

No. VI.—JUNE. 1909.

ORIGINAL ARTICLES.

I.—Eminent Living Geologists.

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(WITH A PORTRAIT, PLATE IX.)

MANY sciences contribute to the progress of geology, but none is more essential to it than that of zoology. The accurate determination of fossils, which can only be done by a trained systematic zoologist, is a necessity for stratigraphical work, and the broad questions of the geography of past ages can only be discussed with the aid of those who understand the distribution of life in the existing world. Dr. Traquair, the eminent ichthyologist of Edinburgh, though scarcely a geologist in the strict sense of the term, may therefore be claimed as one of the leaders in our science, for he has devoted more than forty years to the interpretation of fossil fish-remains, and so laid the foundations of a precise knowledge of extinct fishes which is as important to the stratigraphical geologist as to the biological philosopher.

Ramsay Heatley Traquair was born on July 30, 1840, at the Manse of Rhynd, Perthshire. He was the son of the Rev. James Traquair, minister of the parish, a Midlothian man, who had married Miss Elizabeth Mary Bayly, a native of London. He received his early education in Edinburgh, first at a preparatory school in the suburb of Newington and then at a more advanced school known as the Edinburgh Institution. Being of slight physique compared with other boys of his own age, he found himself unable to compete in games of strength; but being of a quiet and studious disposition and clever at his lessons, he was generally a favourite with his teachers.

Already as a child he showed an ardent love of Nature, both from an æsthetic and from a scientific standpoint. He eagerly read the few books on popular science contained in his father's library. When about 10 years of age he began eagerly to collect butterflies and moths, as well as shells of mollusca. Then about six years later he began to frequent a little shop in Edinburgh kept by an old woman, Mrs. Somerville, who dealt in minerals, rocks, fossils, and foreign

shells. Here his interest was vastly aroused by the fossils which the good lady had for sale, and as soon as possible he procured a copy of Page's "Introductory Textbook of Geology", borrowed a copy of McLaren's "Geology of Fife and the Lothians", and armed with a hammer set out on Saturdays and holidays to teach himself field geology as well as to collect all the fossils he could come across.

When hammering one day among the ironstone nodules contained in the Lower Carboniferous shales deposited on the shore at Wardie, near Edinburgh, he came on a portion of a Palæoniscid fish, a wonderful find (!), though the bones of the head were much crushed and broken, but this only stimulated all the more his curiosity to know how they were conformed and arranged. Impelled by this desire for knowledge, he diligently searched for more specimens, but though better ones did turn up, the craniological problem remained unsolved, and he was content to wait for the time when as a University student he would have access to Agassiz's great work, of which he had already heard, and from which he expected all the enlightenment which he craved. He was blissfully ignorant of the fact that the knowledge of the cranial osteology of fossil fishes was as yet only in its infancy.

As he was approaching the age of 17, the time for the choice of a profession had arrived. He had for years cherished the idea of devoting his life to research in the field of natural history, but as it was necessary to have some means of living to fall back on, he chose medicine as offering likewise an admirable training in biological science. Indeed, at that time the doctorate of Medicine was the only University degree in Scotland which testified to such a training. Accordingly, in November, 1857, having passed his preliminary examination, he entered the University of Edinburgh as a student in the Faculty of Medicine. The first thing he did on finding himself entitled to the privileges of a "Civis Academiæ Edinensis Jacobi Sexti" was to rush to the library and demand a sight of Agassiz's "Recherches sur les Poissons Fossiles", but, alas! he did not find there the much desired light on the cranial structure of Carboniferous fishes. That was evidently a subject for future research.

During the next five years Dr. Traquair applied himself to his medical studies and stood well in his classes, although he had resolved not to go in for practice if he could find an opening in the direction of pure science. His favourite subjects were anatomy and zoology, and in holiday time he continued to collect fossils, paying of course especial attention to those of a fishy description. The skill which he acquired in the art of dissection brought him under the notice of the Professor of that subject, the eminent John Goodsir, by whose advice he took up the subject of the Asymmetry of the Flatfishes for his thesis, for which on Graduation Day, August, 1862, he was awarded a gold medal by the Faculty of Medicine.

In 1862–3 Dr. Traquair acted as Prosector to Professor Goodsir, and was employed in making comparative anatomical preparations. From 1863 to 1866 he was Demonstrator of Anatomy in the University of Edinburgh under Professor Goodsir, and he published his thesis on the Asymmetry of the Flatfishes in the Transactions of the Linnean Society in 1866. In the latter year he was appointed Professor of

Natural History in the Royal Agricultural College, Cirencester, where his principal duty was the teaching of botany to agricultural students. Here he studied Oolitic geology and collected many fossils, but had no longer any opportunity to collect Carboniferous fishes. In 1867 he published his first paper on fossil fishes, entitled "Description of *Pygopterus Greenocki*, Agass., with Notes on the Structural Relations of the genera *Pygopterus*, *Amblypterus*, and *Eurynotus*", in the Transactions of the Royal Society of Edinburgh. This paper was important as containing the beginnings of his original work on the Palæoniscidæ and Platysomidæ, though it suffered in completeness by being founded entirely on specimens collected by himself in the neighbourhood of Edinburgh.

In the month of August, 1867, Dr. Traquair was appointed by the Lords of the Committee of Council on Education Professor of Zoology in the newly constituted Royal College of Science, Dublin, this college being in fact a new development of the old "Museum of Irish Industry". This new appointment afforded him more congenial occupation than teaching botany to agricultural students, though owing to the comparatively small amount of the endowments it could not be looked upon as a permanency. He remained six years in Dublin, but during that time he did not write much. One paper on the imperfectly known Carboniferous Dipnoan fish, *Uronemus lobatus* of Agassiz, attracted the attention of Sir Philip Grey-Egerton, at that time the leading authority on palæichthyology in Great Britain, and gained for him the personal acquaintance both of Sir Philip and of his friend the Earl of Enniskillen, so well known for his magnificent private collection of fossil fishes.

In the autumn of 1873 Dr. Traquair was transferred to Edinburgh to occupy the post of Keeper of the Natural History Collections in the Museum of Science and Art, now, since 1902, known as the Royal Scottish Museum. At that time the "Natural History" Collections in that Museum included also the mineralogical and palæontological collections as well as those of recent zoology. Though his time was much more occupied by official work than in Dublin and his vacations curtailed, he had now the wished-for opportunity of devoting himself seriously to fossil ichthyology as a speciality, for the Museum already contained a large collection of Scottish fossil fishes, including the Hugh Miller Collection and the specimens collected by John Fleming and by Robert Jameson, besides which the Carboniferous rocks round Edinburgh were and are extremely rich in fossil fishes and fish-remains. In his official capacity he was enabled by fresh purchases year by year to develop the fossil fish collection, and more especially that part which was Palæozoic and Scottish, to a high degree of excellence. This was especially desirable in a *Scottish* National Museum, for it is the wonderful richness in fish-remains of its Devonian and Carboniferous strata which especially distinguishes the palæontology of the northern part of the island of Great Britain. Dr. Traquair retained his Keepership for thirty-three years, and retired in August, 1906, having obtained extension of time for one year after reaching the age-limit of 65 years. During that time he also held the Swiney Lectureship in Geology at the British Museum, the

patronage of which is vested in the Trustees of that institution, for two periods of five years each, namely, from 1883 to 1887 inclusive and from 1896 to 1900 inclusive. In this capacity he had to deliver each year a course of twelve lectures, and naturally the subjects which he chose for his lectures were always palæontological.

Besides by the specimens of fossil fishes under his charge in the museum at Edinburgh, Dr. Traquair was much assisted in the way of material by successive Directors-General of the Geological Survey (Sir A. C. Ramsay, Sir A. Geikie, and Dr. Teall), who placed at his disposal for description the fish-remains collected by the Survey in Scotland, some of his best material having come to him from that source.

At the time of his leaving for Edinburgh he married the daughter of Dr. William Moss, of Dublin, and Mrs. Traquair prepared a beautiful series of drawings of Palæoniscid fishes to illustrate some of his works.

Dr. Traquair's original writings appear chiefly in the Transactions of the Royal Society of Edinburgh, in the Proceedings of the Royal Physical Society of Edinburgh, in the Geological Magazine, in the Annals and Magazine of Natural History, and in the volumes issued by the Palæontographical Society. As he always has consistently maintained that palæontology is simply a part of biology, his own work was from the beginning based on morphological structure and not on the mere outline of body or configuration of scales and teeth. He showed from their structure that the Palæoniscidæ were more allied to *Polyodon* than to the Lepidosteoid Ganoids, and that consequently their place was with the Sturgeons (Acipenseroidei), and that the Platysomidæ were a specialized offshoot from the Palæoniscidæ. Indeed, his work on these two families may be said to have given the deathblow to the Agassizian idea of the classificatory importance of the external forms of scales. He was the first clearly to prove that the Devonian genus *Cheirolepis* was not Acanthodian but Palæoniscid, though this had been already hinted at by previous writers. In like manner he settled the question as to *Dipterus* being referable to the Dipneusti, and showed that it agreed in all essential points of structure. He described the remarkable fish-fauna collected by the Geological Survey of Scotland from the Upper Silurian rocks of Lanarkshire and Ayrshire, and showed that the Cœlolepidæ, though in his opinion probably derived from an Elasmobranch source, were not sharks but Heterostracan Ostracodermi. And the Ostracodermi he divided into four families, viz., the Cœlolepidæ (*Thelodus* and *Lanarkia*), the Psammosteidæ (*Psammosteus*), the Drepanaspidæ (*Drepanaspis*), and the Pteraspidæ (*Pteraspis*, etc.), and showed how that the mail-plates of the three last families were evidently formed by the fusion of the small Cœlolepid scales with each other and with hard tissue developed in a deeper layer of the skin. He maintained that the Osteostraci were more nearly related to the Heterostraci than had previously been supposed, the minute tubercles covering the outside of the dermal plates of *Cephalaspis* being suggestive that the superficial layers of these plates were also formed by the fusion of Cœlolepid scales. He also devoted special attention to the Asterolepidæ or *Pterichthys* family,

and his monograph (Palæontographical Society) of the British genera and species of the family is now all but complete.

Dr. Traquair commenced the systematic study of the fishes of the Old Red Sandstone in 1887, and found their nomenclature in much need of rectification. He pointed out how that Agassiz and M'Coy had, misled by appearances dependent on different conditions of preservation, most unnecessarily multiplied the number of supposed species, e.g. he reduced six supposed species of *Cheirolepis* to a single one! Our knowledge of the genera and species of British Carboniferous Palæoniscidæ (on a monograph of which he is still engaged) is principally due to his work. He was the first to figure and to describe in detail the Lower Devonian fishes of Gemünden in Western Germany. His papers on that subject contain a complete account, fully illustrated, of the remarkable mailed fish, the *Irepanaspis Gemündenensis* of Schlüter, which was previously very imperfectly known. It must also be added that he has produced a great many restorations of fossil fishes for the illustration of his papers, and these have been freely copied in all modern textbooks of geology and of palæontology.

Dr. Traquair has received many well-deserved honours, and the thoroughness and value of his published work are universally acknowledged. He was elected a Fellow of the Royal Society of London in 1881, and received the Honorary Degree of LL.D. from the University of Edinburgh in 1893. He was awarded the Neill Medal of the Royal Society of Edinburgh in 1878, and the MakDougall-Brisbane Medal of the same Society in 1901; the Lyell Medal of the Geological Society of London in 1901; and a Royal Medal of the Royal Society of London in 1907. He is esteemed both abroad and at home as the doyen of palæichthyology and the pioneer in its modern methods, and it is the fervent wish of his many friends that he may long be spared in his retirement to pursue the studies which he has so greatly adorned.

LIST OF SCIENTIFIC WRITINGS.

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1863. "Note on an Abnormality in the Ossification of the Parietal Bone in the Human Fœtus": Nat. Hist. Review, pp. 132–3, woodcut.

1865. "Observations on the Development of the Pleuronectidæ": Proc. Roy. Phys. Soc. Edin., vol. iii, pp. 215–22.

1866. "On the Asymmetry of the Pleuronectidæ as elucidated by an examination of the Skeleton in the Turbot, Halibut, and Plaice": Trans. Linn. Soc., vol. xxv, pp. 263–96, 4 plates.

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1882. "New Fish Remains from the Blackband Ironstone of Borough Lee, near Edinburgh," No. III: GEOL. MAG., Dec. II, Vol. IX, pp. 540–6.

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"On *Harpacanthus*, a new genus of Carboniferous Selachian Spines": Ann. and Mag. Nat. Hist. (5), vol. xviii, pp. 493–6, 2 woodcuts.

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II.—Albitization of Basic Plagioclase Felspars.[1]

By E. B. Bailey, B.A., and G. W. Grabham, M.A.

(PLATES X AND XI.)

SINCE Cathrein[2] in 1883 investigated the nature of saussurite, it has been well known that albite can arise from the alteration of basic plagioclase felspars. He found that the fine-grained aggregate of minerals known as saussurite has commonly been derived from basic felspar, and that the processes involved in the change have led to little more than a chemical re-arrangement within the limits of the original felspar crystal. The bulk composition of the aggregate thus agrees approximately with that of the felspar from which it has been derived, and the albite which separates out is intermingled with lime-bearing silicates such as epidote, zoisite, and garnet.

Later, Termier[3] has demonstrated the frequent production of albite in the metasomatism of basic plagioclase felspars under conditions which have led to a complete elimination of the original lime. Although the changes investigated by Termier are quite distinct from saussuritization, it is not clear how far they are comparable with what may properly be termed albitization. The albite he refers to is for the most part merely the residue of the original plagioclase, "des matières étrangères formant le tiers ou la moitié, ou même les deux tiers du volume total" (p. 186). He does, however, deal with examples where an actual gain of soda (p. 190) appears to have resulted. Here there would seem to have been a partial replacement of the original lime-felspar by soda-felspar, and this change, which may fairly be designated albitization, is now known to occur in several widely separated localities. Duparc & Pearce,[4] for instance, have described

[1] By permission of the Director of H.M. Geological Survey.

[2] *Zeit. Krist.*, 1883, Band vii, p. 234.

[3] "Sur l'élimination de la Chaux par métasomatose dans les roches éruptives basiques de la région du Pelvoux": *Bull. Soc. Géol. France*, 1898, vol. xxvi, pp. 165–92.

[4] "Sur les andésites et les basaltites albitisées du Cap Marsa": *Comptes Rendus*, 1900, vol. cxxx, p. 96. Two references to the replacement of potash-felspar by secondary albite may here be inserted: F. Becke, "Zur Physiographie der Gemengteile der Krystallizen Schiefer," *Wien K. K. Akad. Wiss. Denkschr.*, 1906, vol. lxxv, p. 28; and A. C. Spencer, "The Treadwell Ore Deposits, Douglas Island," *Bull. U.S. Geol. Surv.*, 1904, No. 259, p. 74.

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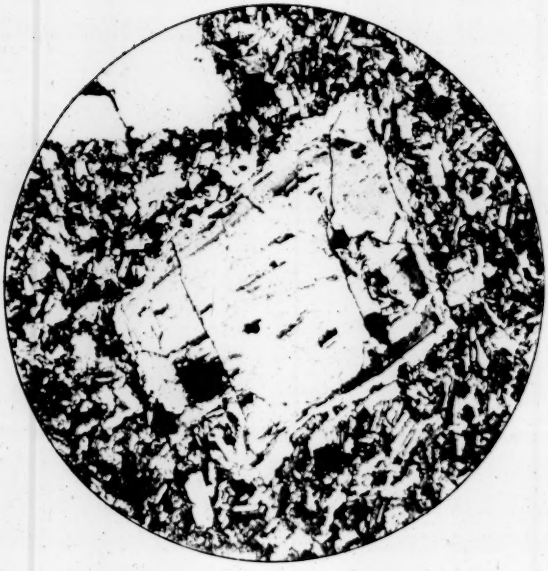

T. C. Hall, Phot.

Microphotographs of Basic Plagioclase Felspars near Lennoxtown.

albitized felspars in certain basalts of Cape Marsa, and we have more recently noticed the same phenomenon in many eruptive rocks of Scotland.

Termier ascribes the production of albite, in the cases which he has studied, to the influence of percolating surface waters,[1] which have above all things leached out the lime from the felspars and other minerals with which they have come in contact. Occasionally, where for some reason the subsoil waters have become unusually rich in soda, they have, according to Termier, been able to leave behind some of this base in partial exchange for the lime removed. More generally, however, the place of anorthite is taken by a silicate containing neither lime nor soda, such as chlorite, and the albite still remaining is merely a residue derived from the original plagioclase. Dupare & Pearce, on the other hand, have not entered upon any theoretical discussion of the processes involved in albitization, while our own experience has led us to regard the change as probably belonging to the category of juvenile reactions which igneous rocks undergo while still hot and richly charged with volatile and soluble ingredients.[2]

Two quite distinct suites of rocks have been specially examined during our inquiry into the rationale of albitization, namely, the Carboniferous lavas and the Permo-Carboniferous intrusions of the Central Valley of Scotland.

Carboniferous Lavas.

Albitization has been noticed among various basaltic and trachydoleritic lavas. It is local in its incidence, for scarcely an example is known from East Lothian, while many occur among the lavas of Arthur's Seat, Edinburgh. Again, in the Cathkin Hills, south of Glasgow, few cases have been discovered, while to the north of Glasgow, in the Campsie Fells and Kilpatrick Hills, every stage leading to complete albitization can be studied (e.g., on the hill-top above Lennoxtown and 150 yards north-east from Carbeth).

The alteration is guided to a notable extent by the cleavage and other cracks of the original felspars, so that kernels and ragged patches of the latter are often preserved in the heart of the secondary albite, and enable us to judge of the composition of the portion which has been replaced. The Campsie and Kilpatrick specimens in the Geological Survey collection demonstrate perfectly clearly that *the more basic the felspar the more liable it is to be albitized*. Thus, in a porphyritic basalt, the phenocrysts are always attacked before the less basic felspars forming the ground-mass, and, in fact, the latter are seldom affected in the least degree until the former have been more or less completely replaced. Not only this, but *in a given felspar the more basic portions are picked out first*, so that even a narrow, alternating zone of more basic composition is replaced, in part at least, before the more acid portions on both sides (Pl. X, Fig. 2); it is, for this

[1] Although not bearing directly upon the point at issue there is much suggestive matter in Sullivan's "Interaction between Minerals and Water Solutions", *Bull. U.S. Geol. Surv.*, 1907, No. 312.

[2] It must be understood that, even if we are correct in ascribing the greater part of the albitization studied by ourselves to juvenile changes, this does not preclude the possibility of Termier's explanation holding good in other districts.

reason, common to find phenocrysts with a core of cloudy secondary albite surrounded by a broad or narrow rim of clear primary felspar of more basic composition (Pl. X, Fig. 1).

The identification of the albite is a simple matter. Its felspathic nature is obvious, since the replacement has been molecular, and the twinning of the original basic felspar has been retained. The refractive index is less than that of balsam, and symmetrical extinctions range up to 16°. It is also the general rule in a composite crystal, cut so as to give symmetrical extinctions, that the extinction, for any particular twin lamella, changes sign where the lamella continues across the boundary separating the albite from the basic plagioclase. Definite cases were investigated in detail according to the optical methods perfected by Michel Lévy, and it was found that the *secondary felspar is albite in the strict sense*, and that *in some cases it replaces felspar originally containing, according to Michel Lévy's stereograms, no less than 80 per cent. of anorthite.* The albite in general does not appear to contain cavities corresponding with the disappearance of the anorthite, for in a great number of instances the total bulk of its inclosures is quite trivial. So much is this the case that there are slides in which it is an open question whether the albite is primary or not, and others (Pl. X, Fig. 1) where a single phenocryst betrays its history by retaining a tell-tale scrap of the original basic plagioclase. There can thus be no doubt in many examples of *a marked introduction of soda into the altered felspar crystals.*

When we inquire into the source of this introduced soda, we find one fact which stands out with special significance. We have seen that, within the limits of any particular felspar crystal, the more basic zones are the more liable to albitization, and that, within the limits of any particular lava, the more basic felspar crystals are preferentially attacked; but now we find the seeming paradox that, within the limits of any particular volcanic district, *the more basic lavas have escaped with less alteration than their neighbours.* If, with Termier, we ascribed the change to the action of percolating surface waters, the exact reverse would have been anticipated, for the basic basalts, on the whole, contain the more basic varieties of felspar. This relative immunity of the more basic lavas is especially well exemplified in Arthur's Seat, where the lower basic portion of the volcanic sequence, and also the well-known basic intrusions of the vent, have escaped unaltered, while the upper, less basic portion of the lava group, consisting originally of highly felspathic basalts and mugearites, has been very extensively affected. In this selective principle we notice at once an analogy between albitization and silicification, and it is reasonable to suppose that the change is of the nature of self-digestion, or, to borrow a convenient term from physiology, of *autolysis.* The soda introduced into the altered basic felspars probably belongs to the lava itself, and so far as this base is concerned the revolution is a matter of internal politics.

The inquiry cannot cease here, for it is of importance to determine, if possible, the stage in the history of the rock when albitization occurred. If it be conceded that the soda introduced into the altered felspars belongs properly to the lava containing these felspars, then it

becomes apparent that the albitization cannot have been accomplished by mere weathering. The fact is there is no available source of soda in the rocks as we find them to-day; for, while they are practically holocrystalline, their felspars are the only soda-bearing minerals present, and it will be remembered that of these it is the more basic members which are first transformed.

But it is certain that the process of albitization does not antedate the crystallization period of the ground-mass felspars; where the core of a phenocryst has been replaced the boundary between core and rim is quite irregular; when examined closely the albite extends along cracks out into the rim, and it is obvious that the latter had formed before the alteration took place. Then, too, the ground-mass felspars are occasionally themselves albitized. We are thus led to suppose that the albitization was performed shortly after the consolidation of the ground-mass, and that the agency at work consisted of residual solutions. We may advance the hypothesis that in certain volcanic centres, e.g. Arthur's Seat, some portions of the magma were discharged exceptionally rich in carbon dioxide (or some other unknown constituent); that during crystallization of the lava an unusual proportion of soda was thus retained in solution; and that the residual liquors then began to react with the minerals which had crystallized. Olivine was converted into serpentine and chlorite, while the most basic felspars were replaced by albite. The process may be crudely expressed by saying that *the lava at this stage was stewing in a concentrated solution of sodium carbonate.*

Many specimens from Arthur's Seat, where albitization has proceeded unusually far, offer additional support to the interpretation given above. It is common to find the vesicles of these rocks lined with beautiful little, inwardly radiating crystals of albite, forming a definite outer layer. An inner layer of chlorite, either pennine (11,991)[1] or delessite (12,027), follows the albite, while the centres of the vesicles are occupied by calcite. It is also a feature of these vesicles that they frequently communicate one with another by means of branching cracks, which are usually entirely occupied by albite (Pl. X, Fig. 2). The cracks traverse phenocrysts and ground-mass alike, showing that the lava had consolidated at the time of their formation. The albite occupying them is generally crystallized in lath-shaped form, as in the ocellar structures of camptonites, but a marginal layer is often deposited in optical continuity with the albitized felspars which have been broken across. *Thus, in the lavas which have been most completely albitized, there was still a surplus left* to line the vesicles and fill the cracks formed in connection with the same. To claim vesicle minerals as juvenile products is nothing new,[2] and certainly it is difficult to regard the albite of the Arthur's Seat examples in any other light. Chlorite, which we may suppose originated from the decomposition of the original olivine, evidently crystallized out of solution after the albite, and last of all came calcite.

[1] The numbers given in parentheses refer to slides in the Geological Survey collection.

[2] Cf. A. Harker, "The Tertiary Igneous Rocks of Skye": *Mem. Geol. Survey*, 1904, chap. iv.

We may now briefly notice some of the peculiarities which the secondary albite of these rocks presents.[1] In one specimen from the Arthur's Seat volcano small patches and veins of anorthoclase accompany the albite, where this replaces phenocrysts, but such an occurrence is certainly rare in Scotland. A universal feature, however, is the presence of minute flakes of white mica (of sericitic appearance) scattered through the albite, wherever this latter has replaced basic felspar; the mica is absent, however, from the albite of the veins and vesicles, so that it has probably arisen independently in the pseudomorphs and is not a mere weathering product of the albite. Much time was spent in confirming the identification of this mineral as white mica. It occurs in such small flakes that its polarization tints are often lower than those of augite in the same slide, while, where closely packed, it gives, with the albite, a most misleading low aggregate refractive index as determined by the Becke effect. In some instances, however, patches can be found with a higher refractive index than chlorite (13,080), while it resists the attacks of acid, and its greatest axis of optical elasticity is normal to the cleavage. It thus appears to be identical with the sericites of other localities whose composition has been determined by analysis. It would be interesting to know whether the mica here is muscovite or paragonite, i.e. potash or soda bearing, but as a rule its bulk is too small to be a matter of much importance as affecting the composition of the pseudomorphs. Chlorite is commonly associated with the secondary albite; sometimes it fills the central portions of the pseudomorphs, sometimes it occupies the site of some particular zone (13,119) of the original plagioclase. It will be remembered that in the vesicles chlorite crystallized immediately after albite, so that the appearance of chlorite as a fairly frequent but subordinate constituent of the pseudomorphs is not surprising. As one might expect, the occurrence of calcite in this position is less frequent, but occasional examples are found (13,115). In a unique slide from the Edinburgh City cutting, at the back of the Engine Shed, St. Margaret's Works, a group of phenocrysts occurs replaced by calcite containing unorientated crystals of water-clear albite. In the same slide a broken albitized felspar has received a thin coat, apparently of chlorite, and later an outgrowth of water-clear albite, in optical continuity with itself; the outgrowth in this case projecting forward into a calcite vein. It seems that in these instances the complete precipitation of the secondary albite was delayed beyond the chlorite stage, and thus it happens that the mineral, elsewhere clouded with minute inclusions, is here water-clear. Analcite (12,307) is an occasional associate of the albite in the pseudomorphs, and at least a couple of other undetermined minerals have been noticed in one or two of the slides. Epidote occurs not uncommonly in small amount in the vesicles and groundmass of these albitized rocks (1191), but not in the felspars themselves. It doubtless contains part of the lime removed from the felspars, but

[1] The minerals mentioned in this paragraph have, in other cases, undoubtedly arisen through weathering. It is probable that juvenile and weathering reactions frequently follow the same course, but that the former, under suitable conditions, proceed with a much greater velocity.

most of this latter has probably been carried off in solution as calcium carbonate.

Permo-Carboniferous Intrusions.

These rocks are quartz dolerites, occurring as sills and dykes; in composition and age they agree with the well-known Whin Sill of Northumberland. Albitization is a very widespread phenomenon among these intrusions, e.g. in the North Queensferry Sill (12,181). It presents the same features as have just been described in connection with the lavas, only here there is a much greater development of finely divided white mica.

The interesting feature of the Scotch Permo-Carboniferous intrusions in connexion with the problem of albitization depends upon the fact that they carry numerous short irregular *segregation veins very rich in albite*. These are of two classes, described by Falconer[1] as 'red', or 'iron band' and 'blue band' respectively.

	A.	B.	C.
SiO_2	64·54	71·26	71·18
TiO_2	1·22	0·28	0·48
Al_2O_3	13·63	11·87	14·89
Fe_2O_3	0·22	0·10	2·11
FeS_2	1·735	0·256	
FeO	4·83	2·12	1·21
MnO	0·20	0·06	
MgO	1·25	1·08	0·14
CaO	2·31	2·88	0·82
Na_2O	5·21	6·73	6·85
K_2O	2·28	0·054	1·70
SO_3	trace		
F	0·056	0·009	
P_2O_5	0·32	0·10	
H_2O (combined) + CO_2	1·86	2·71	0·64
Moisture	0·84	0·62	0·24
	100·50	100·12	100·26

A. Blue band, from quartz dolerite, Carriber Quarry, Linlithgow. Analysed by G. S. Blake, quoted from Falconer.

B. Red band, from quartz dolerite, Kettlestoun Quarry, Linlithgow. Analysed by G. S. Blake, quoted from Falconer.

C. Soda-aplite, from quartz gabbro, St. David's Head, Pembrokeshire. Analysed by A. V. Elsden, Q.J.G.S., 1908, vol. lxiv, p. 284.

There is no very satisfactory sliced material of blue band in the Survey collection, but the red bands (13,777, 12,181) are clearly seen to be pink felspathic veins, carrying a fair amount of quartz, with a small proportion of accessory minerals. The felspars, which are seldom free from white mica, occur in neat laths, with trachytic

[1] "The Igneous Geology of the Bathgate and Linlithgow Hill": *Trans. Roy. Soc. Edin.*, 1906, vol. xlv, p. 133.

arrangement, while the quartz is interstitial and sometimes micropegmatitic. Calcite occurs not infrequently, filling the centres of drusy cavities lined by quartz crystals. Analysis proves the absence of orthoclase, so that the nature of the felspar is sufficiently indicated by the fact that its highest refractive index is well below the lowest of quartz.

Now, one cannot but recognize that these segregation veins present a close analogy with the albite veins connecting vesicle to vesicle in the lavas of Arthur's Seat, while at the same time their juvenile origin is so obvious that it has been taken for granted by every writer on the subject. They are so numerous, too, that it is clear that, during the period of their crystallization, the heated interior portions of the sills must have been permeated through and through by soda-rich solutions. It is very difficult to avoid the conclusion that it was under these propitious conditions that the albitization of the originally basic felspars of the consolidated rock was accomplished, together with the production of much of the accompanying white mica.

It will thus be seen that the evidence derived from a consideration of the Permo-Carboniferous intrusions lends some support to the view already arrived at in regard to the processes involved in albitization as exemplified in the Carboniferous lavas. In conclusion, the analogy between this change and another well-known type of decomposition, prevalent in certain igneous rocks of Scotland, may perhaps be alluded to. Dr. Flett has found, in the Midlothian teschenites, a replacement of basic soda-lime felspar by analcite, similar to the replacement by albite in the quartz dolerites, and he regards the change as juvenile or pneumatolytic in character. That analcitization and albitization may be very closely comparable phenomena will readily be granted when it is remembered that, chemically,

$$\text{analcite} + \text{silica} = \text{albite} + \text{water}.$$

EXPLANATION OF PLATES X AND XI.

Microphotographs by Mr. T. C. Hall.

Fig. 1. × 29 dia. Crossed nicols. Basic plagioclase, phenocryst all but completely replaced by secondary albite. A ragged patch of the original felspar shows clear white near the top of the slide. (13,119.) 1400 feet S. 30° W. from cairn on Lairs, above Lennoxtown, Campsie Fells.

Fig. 2. × 43 dia. Crossed nicols. Zoned plagioclase phenocryst. The more basic portions have been preferentially albitized. The centre consists almost wholly of secondary albite, showing white; and an alternating basic zone, showing dark near the top corner, is being preferentially replaced by patches of albite. (13,082.) Crichton's Cairn hill-top above Lennoxtown.

Fig. 3. × 22 dia. Centre of felspar phenocryst entirely replaced by cloudy secondary albite. The rim is plagioclase (not orthoclase), more basic than albite, but doubtless less basic than the original felspar of the central portion now replaced. (12,280.) 100 yards north-east of north corner of Auchencloch Plantation, Kilpatrick Hills.

Fig. 4. × 22 dia. Crossed nicols. Albitized basalt with albite vein. A small round vesicle, filled with albite, is seen just below the vein and communicating with it. These veins appear merely to connect up neighbouring vesicles with one another and not to traverse the rock for any distance. (12,027.) Calton Hill, path opposite west wing of High School, Arthur's Seat volcano.

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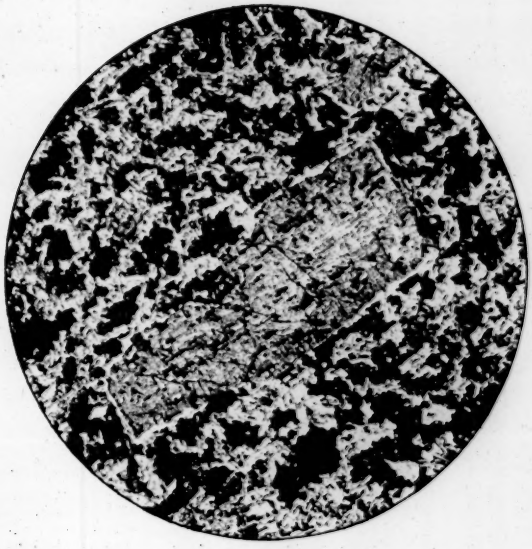

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T. C. Hall, Phot.

Microphotographs of Basic Plagioclase Felspars.
3. Kilpatrick Hills. 4. Arthur's Seat.

III.—The Depth and Succession of the Bovey Deposits.[1]

By A. J. Jukes-Browne, B.A., F.G.S.

In the report of an excursion organized by the Geologists' Association to Newton Abbot in 1900, Mr. H. B. Woodward stated that a boring had been made by Messrs. Candy & Co. at Heathfield, near the middle of the Bovey Basin, and that it "had been carried to a depth of 520 feet from the surface through clays, sands, and lignites without reaching the base".

As this is the deepest boring which has yet been made in the Bovey Basin, and as no further particulars have yet been published, I applied to Messrs. Candy & Co. for any information that they could give me, and I have their permission to publish the following particulars, with which they were kind enough to furnish me.

The site of the boring is the great clay-pit belonging to Messrs. Candy & Co. close to Heathfield Station, about 3½ miles north-west of Newton Abbot. The depth of the pit is actually 70 feet, and the boring was started on its floor; it was carried down to 456½ feet, so that the depth reached was 526½ feet from the surface, this level being about 90 feet above the sea (O.D.).

The 70 feet of strata exposed in the pit include some 20 feet of superficial deposits of post-Eocene age, gravel, sand, and clay; below these are beds of clay, with one bed of lignitic material about 7 feet thick and a lenticular bed of sand. The first 100 feet of the boring traversed various beds of clay and sand with four beds of lignite. In the next 100 feet only one bed of lignite was met with, but below 200 feet lignites predominated to such an extent that the material traversed is described as consisting principally of "lignite in thick beds divided by layers of brown clay, the beds of lignite being much thicker than those of clay, and the thickest lignite having a depth of over 20 feet". No beds of sand were met with below a depth of 300 feet. The bore ended in a bed of lignite.

The information above given may be summarized as follows:—

	Feet.
Superficial deposits, gravel and sand	20
Clay, with some beds of sand and one of lignite	50
Beds of clay and sand, with four of lignite	100
Beds of clay and sand, with one of lignite	100
Beds of lignite and clay, with a thin bed of sand at 300 feet	36
Beds of lignite divided by layers of brown clay	220½
	526½

Mr. Woodward states that the dip of the Eocene beds seen in the open pit is 8° to the W.S.W. If the total thickness of Eocene deposits proved by the boring is taken as 500 feet, and allowance is made for the dip, the exact thickness of the beds at right angles to the dip may be stated as 493 feet.

The chief interest of this succession of deposits lies in the fact that beds of lignite predominate so greatly in the lower part, and that beds of sand only occur in the upper 300 feet. When we remember that

[1] A paper read before the Geological Society on February 5.

the basement beds of the series, as seen on the borders of the basin, consist of sands and gravels, such a succession as that proved by the boring is just the opposite of what one would expect.

The marginal beds above mentioned are not shown on the published map of the Geological Survey, because when the survey was made, many years before the issue of the map, these gravels and sands had not been separated from others of post-Eocene date. Mr. Woodward informs me that they hope to remedy this omission, and to prepare a new edition of the map in the course of this year. So far as I have been able to ascertain, the basal gravels do not extend all round the basin, but are principally found on its eastern and south-eastern sides. On the eastern side, from Kingsteignton northwards to Bellamarsh, there is a nearly continuous border of sand and gravel which appears to pass westward under the clays and lignites which have been so extensively worked near Abbrook, Preston, and Knighton. The material is largely sand, but whether there is always gravel beneath the sand has not yet been definitely ascertained, nor have certain tracts of more recent gravel been separated from the older deposit.

I think it will be found that the Eocene gravel is practically restricted to this eastern side of the area and to the small subsidiary basin south and east of Newton Abbot, while round the western half of the main basin, i.e. that part which lies to the west of the River Teign, the basement beds consist of sand, though in places (as at Staple Hill) there are pebbles and blocks of chert in this sand.

The succession proved in the boring is interesting from another point of view, for it confirms the conclusion arrived at by Pengelly in 1861[1] with respect to the relative age of the beds exposed in the 'old coal-pit' south-east of Bovey Tracey. The section recorded by him as seen in this pit below the 'Head' may be summarized as follows:—

	ft.	in.
Beds of clay, sand, and lignite	19	4
Clays with three beds of lignite	15	0
Thick beds of lignite with thin clays	18	10
Sand (11 feet) and clay (9 feet) below	20	0
Alternating beds of clay and lignite	22	0
Thick beds of lignite with thin seams of clay	22	6
	117	8

From the information communicated by Mr. J. Divett, who then owned this pit, Pengelly showed that a fault must cross the area to the south-east of the exposure. At the old engine shaft 112 yards east of the pit the succession proved (according to Mr. Divett) was the same, but 140 yards further east he made a boring in 1855 to a depth of 99 feet, and traversed a very different set of beds. These consisted of sand and clay in alternating beds, with only one thin layer of lignite, the clay beds varying from 3½ to 10 feet and the beds of sand from 1½ to 13 feet in thickness; the total thickness of sand is 47 feet and that of clay about 39 feet.

[1] See the memoir by Pengelly & Heer, Phil. Trans. for 1862, and issued separately as a volume entitled *The Lignite of Bovey Tracey*, 1863.

Commenting on this fault, Pengelly concludes that "the beds on the east of it are an upper portion of the Bovey deposit, preserved through the intervention of a vertical displacement of at least 100 feet from the denuding action which swept it away on the west". From the particulars stated, it appears that the fault runs very near to the old engine shaft, and it is clear that Pengelly's inference as to the arenaceous series being newer than the lignitic series is based on the similarity of the former to the highest beds in the pit-section.

He also notices the curious fact that the lowest beds found in the 'old coal-pit' consisted entirely of lignites and clays for 53 feet, when a thin bed of sand occurs, and further that above this another thick set of clays and lignites was formed before any more sand was introduced into the area, but he does not suggest any satisfactory explanation of these facts.

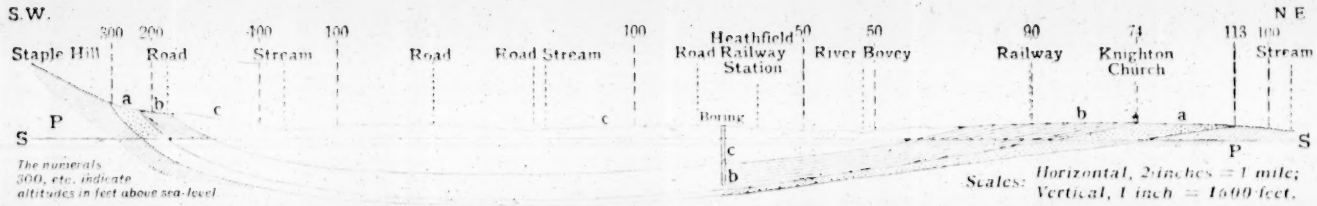
The boring at Heathfield confirms the succession described by Pengelly at the old workings near Bovey, which are about 2 miles to the north-west of it, and proves moreover that the lower lignitic beds are much thicker than he had any reason to suppose.

The highest Eocene beds seen at the Heathfield Potteries are white clays with an interbedded stratum of black clay and lignite, but these are not likely to be the highest beds in the basin, since the dip there is westward, and the ground rises somewhat in that direction. It is indeed very probable that the beds proved by Divett's boring and recorded by Pengelly are newer than any in the Heathfield pit, since by the presence of thick beds of sand they differ as much from the Heathfield section as from the Bovey pit-section.

I think, therefore, we may fairly add at least 90 feet to the total of the Heathfield boring, and as this did not reach the base, but ended in lignite, the bottom of the basin is not likely to be less than 30 feet lower. The total thickness of the Eocene deposits may therefore be estimated at $493 + 90 + 30 = 613$ feet. Finally, we must remember that the series is abruptly truncated at the top.

Of course, it does not follow that the succession proved in the boring and for the western part of the basin should hold good for the eastern part. Near Kingsteignton the pits worked are chiefly in clay, with occasional beds of sand and very little lignite, but their position in the series is not definitely known. The pits worked near Preston, 2½ miles north of Newton, on both sides of the road to Chudleigh, have shown alternating beds of lignite and white clay, both varying in thickness, but both reaching an individual thickness of 10 feet. The prevalent dip here is about 10° to the W.S.W., and the distance from the eastern border of the flat land is about a quarter of a mile; these beds will be about 220 feet above the basal sands.

Here I think we may well ask whether the highest sands and clays, and even the highest lignite and clay of Heathfield, are of the same age as the lignitic series which lies several hundred feet below them. This question can only be answered by a full investigation of the beds themselves and a further search for seeds and other plant-remains. I am glad to learn from my former colleague, Mr. Clement Reid, that he and Mrs. Reid have already entered this field of research and intend to explore it more fully next summer. From what he has told



Section across the Bovey Basin through Heathfield.

me it is evident that the results are sure to be interesting, and that much new botanic material will be obtained.

Until quite recently it has been very generally supposed that the Bovey Basin was a natural lake-basin, and that its present limits were not far within the limits of the original lacustrine area. I have, however, little doubt that the existing basin in which the deposits lie is a tectonic basin, and not in any sense an actual lake-basin. The high dips to the north-east, which are observable on the south-western border of the basin, as at Staple Hill, and which are opposed to the more moderate dips seen at Heathfield and Preston, are sufficient to prove the nature of the syncline.

The Bovey Basin may, in fact, be compared with that of Orglandes near Valognè in the Cotentin, in which marine Eocene and Oligocene beds occur in the form of an outlier separated from the main tract of the Paris Basin. If the Bovey Basin had been filled with marine Bracklesham and Barton Beds, no one would have thought of supposing it to be anything else than a tectonic basin formed by subsequent flexure of the crust. It is only the fact of its contents being entirely of freshwater and terrestrial nature that has perpetuated the very natural mistake which was made by the earlier geologists.

As already remarked, the succession of deposits proved at Heathfield is somewhat remarkable, and the order in which they occur is not what would have been expected if the deposits had all been formed beneath the waters of an ordinary lake. If the Bovey Basin had been part of a lake fed by one or more copious rivers, and if the lignites had been formed by masses of driftwood carried down by these streams during periodical floods, one would have expected the resulting deposits to be an alternating series of sands, clays, and lignites throughout the whole thickness, or possibly an upward transition from gravel and sand through sands and clays to clays and lignites, and finally to the peat and lignite of a silted-up swamp. Instead of this being the case, we have the lignites in the lower part and the alternating series of sand and clay in the higher part.

What, then, are the lignites, and how were they formed? To answer this question we must ascertain what kinds of plants enter into the composition of the lignites. So far as the beds examined by Heer and Pengelly are concerned, they consist of the matted remains of certain trees, ferns, and other plants which seem to have grown and decayed in the place where they now occur.

I am aware that Heer held a different opinion, but I do not think that the facts which he recorded support the view which he expressed. He wrote as follows[1]:—"The lignite beds of the under series consist almost entirely of tree-stems (probably belonging in great measure to *Sequoia Couttsiæ*); these alternate with masses of a brownish-black clay, the dusky colour of which has doubtless been produced by the decomposition of the softer portions of the plant. No leaves offer themselves for recognition, but here and there twigs and seeds and little fruits, as *Carpolithes Websteri* and *C. nitens*. The tree-stems,

[1] *The Lignite Formation of Bovey Tracey*, 1863, p. 25, reprinted from the Phil. Trans. of 1862, pt. ii.

which are piled over one another in huge masses (none of them stand upright) and which every here and there stretch their branches and roots in the layer of clay which has covered them up, have apparently been floated hither, not only from the immediate circuit of hills, but doubtless also from greater distances. Such a mass of timber could hardly have been furnished by the former. Accordingly, we learn from the structure of these lignite beds that they did not originate in a Tertiary peat-deposit, but from a colluvies of wood uniting in a lake."

From the above quotation it is evident that Heer supposed the only alternatives to be either the transport of driftwood into an open lake or the growth of moss in a peat-bog; but there is a third and much more probable method of accumulation, and that is the growth of a forest swamp, like the Great Dismal Swamp of Virginia.

Heer himself admitted (on the same page) that "the entire absence of freshwater shells, and indeed of aquatic animals generally, is certainly very extraordinary; and so is the absence of fruits of *Chara*, which abound elsewhere in Miocene freshwater deposits; the *Nymphæa* seeds, however, afford positive proof of fresh water". He thought that the absence of bog plants might be explained on the supposition that these lignites were formed in the middle of the lake and that the bog plants would not have drifted so far out.

It is now known, however, that the picture of the forest flora given by Heer was based on imperfect information, and that his identifications of some of the plants were not correct. If we turn to the accounts given by Pengelly of the actual composition of some of the lignite beds, and interpret them by the light of more recent knowledge, we shall obtain a rather different idea of the flora, and a very different conception of the conditions under which it grew and flourished.

Pengelly states that the bed of lignite numbered 7 in his section, occurring at a depth of 20½ feet from the surface and having a thickness of 15 inches, was a matted mass "composed of the coniferous tree *Sequoia Coutsiæ* and of the fern *Pecopteris lignitum*".

Of the twenty-fifth bed, which includes over 6 feet of lignite, he says "the lowest 3 inches of the bed is commonly a mat of fragmentary fronds of *Pecopteris lignitum* and *Lastrea stiriaca*, the first being the most prevalent. Above this lie the rhizomes [which Dr. Croker had called 'flabelliform leaves'] in a continuous band about 6 inches thick. . . . The uppermost portion of the bed consists of slabs of 'board coal' of great length, and of a width indicating the existence of trees fully 6 feet in diameter. Bodies occur in this bed having the appearance of roots, with rootlets passing into the clay below".

The twenty-sixth bed is a brown clay 2 feet thick, but has "an almost continuous band of broken lignite at the base" which consists of branches of *Sequoia Coutsiæ* and a number of dicotyledonous leaves.

The forty-sixth bed, at a depth of over 96 feet, is a band of lignite only 9 inches thick, but abounding in the small seeds named *Carpolithes nitens* by Heer. These seeds "are thickly strewed over the surfaces of the laminæ of lignite, and slightly embedded in them, as if the latter had been soft when the deposit was formed".

With regard to the names of the plants above mentioned several alterations have to be made.

In the first place it is probable that the so-called *Sequoia* does not belong to that genus. The same species has been quoted as occurring at Hordwell and in the Hamstead Beds, but Mr. Gardner found that the cones there associated with the leafage were indistinguishable from those of *Athrotaxis cupressoides* of Tasmania, "a small erect tree from 20 to 30 feet high with numerous branchlets which are slender, spreading or pendulous and cylindrical.[1] . . . It is found at Lake St. Clair and along Pine River Valley in western Tasmania." From this it is clear that *Athrotaxis* prefers wet situations like its relative *Taxodium distichum*, which is a notable tree in the swamps of Virginia, Carolina, and Florida.

It has not yet been ascertained if the Bovey tree is the same species, owing to the difficulty of getting well-preserved cones, but the probability of its being the same is great.

Again, the *Pecopteris* of Heer proved to be a species of *Osmunda*, and as many species of this genus thrive best in wet and marshy ground, *O. lignitæ* may well have grown on the very spots where its rhizomes and large leaves are now found in such profusion, and in the same beds of lignite with the *Athrotaxis*.

Lastly, as regards *Carpolithes*, Mr. Clement Reid informs me that it is the fruit of a *Stratiotes*, and may for the present be called *Stratiotes Websteri*. He also tells me that similar fruits occur in the Hamstead Beds, in the Cromer Forest Bed, and in Pleistocene deposits, having also been known under the name of *Paradoxocarpus carinatus*, but that he cannot yet say whether they all belong to one species or not. *Stratiotes* is a water-plant, and the British species is known as the 'water-soldier'. In reply to a question Mr. Reid writes that "judging by the mode of occurrence in the Hants Basin, I should say that *Stratiotes Websteri* was probably a shallow lagoon species which did not mind a little salt. It is found abundantly mixed with fruits of *Limnocarpus*, a genus close to *Potamogeton*".

The evidence afforded by these plants is therefore strongly in favour of the view that the flora of the beds containing their remains is a swamp flora, and consequently that these lower lignite beds have been formed where they are now found by the growth and decay of the plants which occur in them.

Besides those plants which seem to have contributed most largely to the formation of the lignites, the more common forms recorded by Heer are two species of cinnamon, an evergreen oak (*Quercus Lyelli*) said to be "like those seen in Mexico", some species of vines (*Vitis*), the prickly cactus (*Palmacites*), and several species of *Nyssa*, a tree of which several species live in the United States, and one at least is conspicuously a swamp-lover.

In this connection it is important to note another fact, and that is that the Bovey lignites have not, so far as they have been investigated, yielded any mosses, and it is clear that they were not formed after

[1] Mr. G. Smith in his recent book on Tasmania describes the *Athrotaxis* as growing to a height of 40 or 50 feet.

the manner of peat beds in Europe and the more northern parts of America. But it is a fact that south of a certain line of latitude in the United States peat-forming mosses do not flourish, and that they do not occur in the great swamps of Virginia and Carolina. These are forest-swamps with an undergrowth of cane-brakes (*Arundo*), ferns, and other annual plants in the drier parts. In the Great Dismal Swamp the most conspicuous trees are the *Taxodium*, which grows to a height of about 50 feet, the White Cedar (*Cupressus thyoides*), which reaches to 30 feet, and the Black Gum (*Nyssa denticulata*), growing to a height of 40 or 50 feet; and in some parts a climbing grape-vine forms a dense thicket between the trees.[1]

It is certainly, then, to the Great Dismal Swamp on the borders of Virginia and North Carolina that we should look for a modern counterpart of the conditions under which the Bovey lignites were formed. There is no better account of this swamp than that written by Sir C. Lyell and published in his *Travels in North America*, 1842, and there is an excellent summary in his *Principles of Geology*[2] which may here be quoted.

This is "an extensive swamp or morass, 40 miles long from north to south and 25 wide between the towns of Norfolk in Virginia and Weldon in North Carolina. It has somewhat the appearance of an inundated river plain covered with aquatic trees and shrubs, the soil being as black as that of a peat-bog. It is higher on all sides except one than the surrounding country, towards which it sends forth streams of water to the north, east, and south, receiving a supply from the west only.

"In its centre it rises 12 feet above the flat region which bounds it. The soil to the depth of 15 feet [in some places] is formed of vegetable matter without any admixture of earthy particles . . .

"The surface of the bog is carpeted with mosses and densely covered with ferns and reeds, above which many evergreen shrubs and trees flourish, especially the White Cedar (*Cupressus thyoides*), which stands firmly supported by its long tap-roots in the softest parts of the quagmire. Over the whole the deciduous Cypress (*Taxodium distichum*) is seen to tower with its spreading top, in full leaf in the season when the sun's rays are hottest, and when, if not intercepted by a screen of foliage, they might soon cause the fallen leaves and dead plants of the preceding autumn to decompose, instead of adding their contributions to the peaty mass. On the surface of the whole morass lie innumerable trunks of large and tall trees blown down by the winds, while thousands of others are buried at various depths in the black mire below."

From Professor Shaler's account of the Swamp we learn that it rests on unfossiliferous sands derived from a bordering Pliocene deposit, and that there is no great depth of lignitic or freshwater material below the swamp-area. It would seem that the subsidence which led to the formation of the 'Dismal Swamp' was of short duration, but if it had been of greater extent, without bringing in the

[1] See N. S. Shaler, "On the Freshwater Morasses of the United States," in Tenth Ann. Rep. U.S. Geol. Survey, 1888, pp. 261–339.

[2] 10th ed., 1868, vol. ii, p. 505.

neighbouring sea, it is probable that a succession of lignites and thin clay beds would have been formed which would have greatly resembled those of the lower part of the Bovey Series.

The history of the Bovey and Newton Abbot district seems therefore to have been as follows. During the earlier part of the Eocene period, the time represented by the Lower or London Eocene strata, the west of England was a land-surface, and eastern Devonshire was covered by a sloping table of Chalk which was being reduced to the condition of a peneplain by subaerial detrition. After the epoch of the London Clay and Bagshot Sands the south of England seems to have sunk slowly but continuously, allowing the shallow bay or estuary of the Bournemouth Beds to spread farther and farther westward; leading also to the formation of lagoons, lakes, and swamps on the low-lying plains adjoining the rivers which emptied themselves into this bay.

The Bovey and Newton district would be part of this lake-and-swamp area. We know that the granite of Dartmoor was exposed and lay to the west of it, rising doubtless above the level of the swamp land, but not into high and hilly ground as it does at the present day. There may also have been somewhat higher land to the south of it, so that it probably drained eastward or northward. Hence we see that the local conditions, both physical and climatic, were similar to those which have led to the formation of the Dismal Swamp of Virginia; except that the Bovey district was farther away from the seabord of the period, and that continuous subsidence resulted in the accumulation of much thicker masses of lignitic materials.

For a long time it would seem that the vegetation was so luxuriant that in spite of the subsidence the Heathfield swamp was always choked with the decaying vegetable matter which has since been consolidated into the lignite beds. There came a time, however, when the swamp was invaded by the waters of an adjoining lake and the forest was buried under a deposit of lacustrine mud; such invasions became more frequent until at length it was only occasionally that the swampy vegetation could once more establish itself over the same tract of ground.

Finally, if I have correctly interpreted the succession of beds in the Bovey Series, lacustrine conditions were permanently established, and the only deposits formed were white clays and fine yellow sands, both apparently being materials derived from the detrition of Dartmoor. It seems possible that these may be of Oligocene age, but so far as I know there are no open exposures of them, and a special excavation would have to be made for their exploration.

IV.—Wells of the North-Eastern Sudan.

By G. W. Grabham, M.A., F.G.S., Geologist to the Sudan Government.

THE Anglo-Egyptian Sudan territory covers an area of about a million square miles, throughout which the development of communications is of prime importance to the Government. The country varies from barren desert in the north to tropical jungle in

the south, and one passes through all intermediate grades between these extremes. In the area between latitudes 12° and 22° north, water is the most important factor in determining the positions of routes, and it is with part of this area that it is proposed to deal. South of this, water is more abundant and other factors have to be considered.

The country is formed of a series of old sedimentary rocks, among which many different kinds of igneous materials have been intruded. These were subjected to extensive earth movements before the volcanic and intrusive rocks immediately underlying the Nubian Sandstone were erupted. In dealing with our subject we may speak of all these collectively as the Older Crystalline Rocks. They are all impermeable except where they are sufficiently decomposed to allow the water to percolate along joints and pores. The Nubian Sandstone Series rests on these Older Crystalline Rocks and fills up the hollows of the old land surface. This series consists mainly of sandstones, but it also includes beds of clay. As the latter never appear to have any great lateral extent, the whole series may be regarded as permeable.

Artesian conditions have not been met with, and water supplies are dependent on rainfall, seepage from the river, and local geological conditions.

The surface deposits vary with the climate. The rain-bearing monsun only reaches about as far north as Berber, and beyond this the rainfall is limited to showers often with intervals of years between them. At Khartoum we have about 4 inches per annum, and the amount increases as one goes southwards and eastwards. Kassala, due east of Khartoum, has about 12 inches of rainfall, and the following list[1] serves to give an idea of the variation in quantity along a more or less east and west belt, about 120 miles south of these places:—

El Obeid, 12 inches.	Wad Medani, 17½ inches.
Dueim, 8 inches.	Gedaref, 24 inches.

Gallabat, a town south-east of Gedaref, has a rainfall of 33½ inches.

On the Maritime Plain the rain does not accompany the monsun, but occurs in the winter. Suakin has about 12 inches of rainfall per annum.

In regions of the Sudan Plains, where the rainfall amounts to about 8 inches or more, the surface deposit is typically Cotton Soil, and where there is less the conditions approximate to those described by Mr. H. T. Ferrar.[2] The Cotton Soil is very similar to the Indian 'Regur'[3] in physical characters. It is fine-grained, absorbs a very large quantity of water during the rains, and, as this evaporates in the dry season, the soil becomes fissured with wide cracks often 6 feet deep. As far as water supplies are concerned, it is quite impervious, for though it will absorb a large rainfall, it is so fine-grained that the water cannot pass through to reach a porous

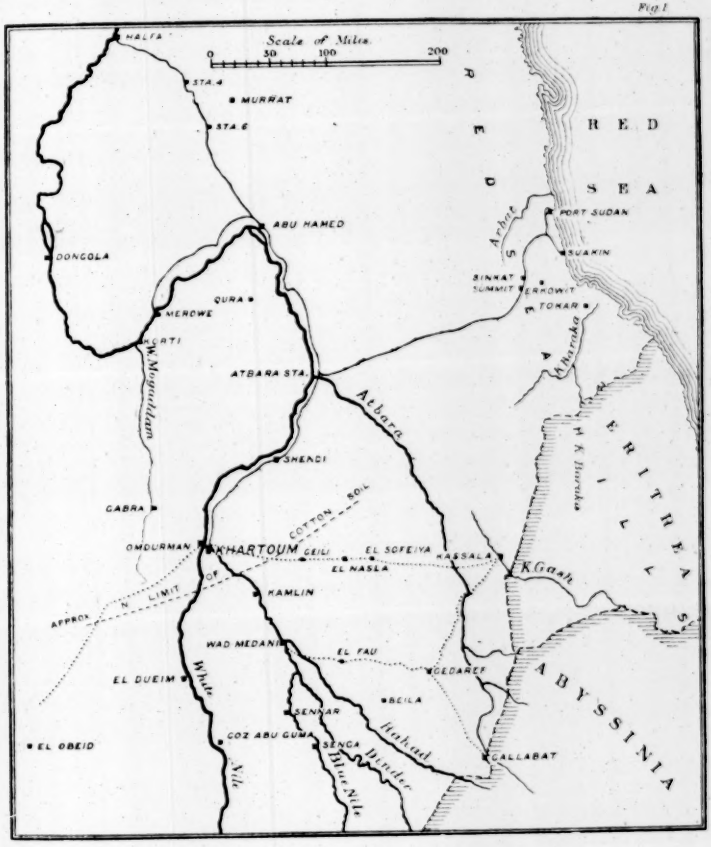
[1] Rainfall statistics derived from *Physiography of the Nile Basin*, H. G. Lyons, Cairo, 1906.

[2] Geol. Mag., 1907, p. 459.

[3] *Manual of the Geology of India*, 2nd ed., revised by R. D. Oldham, p. 410.

rock beneath, should one exist. The amount may vary from the thinnest covering to over a 100 feet in depth. It covers the country like a blanket, forming level plains broken only here and there by hills of hard rock that rise up like islands in a sea.

Fig. 1



From the brief description of the country just given it will be seen that wells can be classified according to the way the water is derived. They fall at once into two groups, namely, those in crystalline areas and those in sedimentary rock. The first group can be divided again according as the wells occur in Cotton Soil districts or in the more arid regions to the north. The wells in the Nubian Sandstone Series are not susceptible to this distinction. We shall now pass on to consider these different classes of wells separately.

A general map of the area (Fig. 1) shows the positions of most of the places mentioned, and a dotted line on it roughly indicates the northern limit of the Cotton Soil.

Wells in Areas of Crystalline Rock covered with Cotton Soil.

A well in such a situation requires very special conditions for its existence. The Cotton Soil is impervious, and attempts to make wells in it generally prove the driest spots during the rainy season when the country around is flooded. The blanket of Cotton Soil must be broken by an 'island' of rock, and then, if the rock is capable of decomposing into permeable material, we have the requisite conditions for a water supply. In all successful cases I have seen the soil is pierced by an igneous rock. The water is held in the decomposed rock and débris round the base of the hill, while the surface of the ground is largely composed of sandy detritus from the hill-slopes, through which the water can pass and saturate the porous material beneath.

A few special cases may be mentioned:—

Geili. The hill is formed of syenite, and around the main one there are several ranges of low hills breaking through the plain. The wells are nearly all situated on the plains that separate the different hills. The water is found at a depth of about 60 feet in soft decomposed rock, and is generally of good quality.

Nasla. The rock here is a felsite, and the water is derived from joints, as the rock does not decompose to a spongy mass. The natives have wells at Um Rueishid, about 8 miles north, and these are in similar rock yielding abundant water. The stone is far too hard for the native to tackle with the implements at his disposal, and so, instead of making a vertical well, he has taken the line of least resistance where the joints allowed him to pick his way, and the shafts are even horizontal in part of their course.

El Sofeiya. These wells are in decomposed granite. There is no actual hill, but the country slopes away in all directions from the granite outcrop. The wells are situated at the top of the rise where the soil is sandy, and there are outcrops of fresh rock around them. The water is obtained at a depth of about 50 feet.

There are many other cases, but those I have mentioned are fairly typical. The water is nearly always good, and only in one case have I found it disagreeable. This was from some wells in decomposed granite, and was found to contain magnesia and sulphates by Dr. Beam, who tested a sample at the Wellcome Research Laboratories.

Water has recently been obtained in a well sunk by the Government at Khor Ogod el Bagar, about 20 miles from the river on the road from El Sofeiya to the Atbara. It is situated in a shallow khor traversing a Cotton Soil plain, and there are no hills within 10 or 15 miles. The rock is a foliated quartz-mica-diorite traversed by pegmatite veins. At the time of my visit the work was in quite fresh rock, and the chances of obtaining water in it seemed very remote. Softer rock appears to have been found as the depth increased, and from this the water is derived. The occurrence of water in such a situation is an exception to the rule, and I think it is more likely to be due to seepage from the river than to local rainfall percolating through the Cotton Soil and fresher rock above. In other cases, where the wells have been situated at a distance from the river, harder and fresher rock was found as the depth increased.

Many of these wells appear to be of very ancient date. There are numbers of stone implements to be found on the surface around some of them, and at Geili there is a stone inscribed with hieroglyphics. Many of the old wells may have been lost or forgotten during the troubles of this country, and it appears that stone implements in a locality may be taken as a clue to the previous existence of water supplies, but it must be borne in mind that these might be found in a place where the supply took the form of rain pools and existed for part of the year only.

The wells of the Gedaref district may be mentioned here. They derive their water from an outlier of the Abyssinian Plateau Basalts resting on the Nubian (?) Sandstone. The natives have dug their wells wherever the rock is soft enough, and the water is obtained at small depths in rotten rock.

Wells in Arid Regions of Crystalline Rock.

The Red Sea is flanked by an area of crystalline rocks where deeply carved valleys are partly filled with gravels and detritus, which form a deposit that we may speak of as Valley Fill. This is the only permeable deposit of the district, as the rocks themselves are not sufficiently decomposed, at any rate on the surface, though they may be so under the Valley Fill. There are exceptions to this, for in some favoured places, where high hills rise close to the Maritime Plain, the rainfall amounts to much more than is usual, supports a rich flora, and under these conditions the rocks are decomposed and become permeable. I mention this as such places, though they cannot be called arid, occur within the region, and are marked by very sharply defined boundaries.

There are no rainfall statistics that apply to this area, for the existing stations are on the seaward edge of the Maritime Plain, and another is at Erkowit, an oasis among the hills. There is evidence that it is extremely small, and perhaps does not exceed 4 inches per annum. The state of preservation of the fort, built of sun-dried mud, at Sinkat points to a figure even less than this. The rain occurs in violent storms that seldom affect an area of more than a hundred square miles in extent, and the resulting stream generally flows beyond it. When a shower occurs the water is soon coursing down the hill-sides, and forms a surface stream on the broad valley bottom. The gradient is enough to allow of a rapidly flowing stream, chocolate-coloured, with fine sand and mud carried in suspension. The Valley Fill is very porous, and the level of the water-table near the new stream rises rapidly. The water is absorbed most rapidly when the stream is flowing fastest. As soon as the flow begins to abate, and the size of the particles that can be carried in suspension begins to diminish, the pores of the stream-bed become clogged and infiltration is checked. The final result of this is that, after the flow has ceased, pools remain in the stream-bed and are maintained by a thin film of mud which prevents percolation into the dry sand beneath. It has been proved by holes in the sand near the edge of these pools that the level of the water-table was below that of the pool. It appears, then, that the rate of percolation from a stream into

its bed is a function of the size of particle it can carry in suspension, and, consequently, of the speed of the current. I am not aware of having seen this principle put forward before, though, once observed, its truth is apparent.

When the water is absorbed by the Valley Fill it is protected from evaporation, and as it flows slowly down the rock valley it is readily tapped by wells. In Khor Arbat, a valley north-west of Port Sudan, there is a place where the valley narrows and the gravels become constricted in section, with the result that the normal underflow cannot pass and the water is forced out, forming a stream at the surface. This is probably the only place in these arid regions where there is a perennially flowing stream, and it is interesting as containing a small freshwater fauna. There is no evidence of a rock bar across the valley throwing up the water, and the explanation given is sufficient, even supposing that the longitudinal section of the rock valley is a continuous curve.

The wells of this area are all situated in the Valley Fill, from which they derive their water. Where the railway traverses it, a good deal of experience has been gained in sinking wells. From Summit downwards the line follows valleys both towards the Nile and the sea. I can only speak with experience of the seaward side, but Capt. S. F. Newcombe, R.E., tells me that the conditions are similar towards the Nile. The difference of slopes, however, makes the topography very different. In one place on the eastern side he has proved the section of the rock valley beneath the Valley Fill, showing conclusively that there is no need for the line of the surface stream to coincide in plan with the deepest part of the rock valley. This is a point to be borne in mind, for the tendency has been to choose a site near the stream-bed or actually in it. The native ones are probably in the stream-bed as a result of deepening a water-hole, made immediately after the rains, in pursuit of a falling water-table. It appears also that better water is got from wells in this situation than from others at a distance from the bed, and the reason may be that the underflow mainly infiltrates from it and so traverses less Valley Fill in reaching the well. The position of the stream-bed is always marked by trees or denser vegetation, which covers narrow strips of ground alongside it. Seeds have the best chance of germinating and growing up here, as it is the moistest place in the valley, and, once the growth of vegetation begins, the fine dust, whether carried by wind or water, is arrested and forms a good soil among the roots.

As examples of wells in this area the following may be mentioned:—

The Okok wells at Sinkat find their water at a depth of about 30 feet, and are situated high up in the valley, within 7 miles of the watershed. They are in the stream-bed on the north edge of the Valley Fill, and Capt. Newcombe, who dug one of them, tells me that he reached the solid rock only just below water-level. In former times there were other wells at a distance from the bed, but the water is said to have been much inferior to that of the existing ones. There does not seem to have been any attempt to make wells in the middle of the valley, where the Fill is probably deepest.

At Gebeit, lower down the valley and about 14 miles from Summit,

there is a depth of over 110 feet of Valley Fill, and good supplies of water are obtained from it at that depth. The total depth of Fill is not known, but in any case it is a great thickness to find close to the watershed, at an altitude of 2000 feet, in a valley that slopes down to the sea in about 70 miles.

There are other wells lower down this valley, and at Salom, where the Port Sudan and Suakin branches of the railway divide, it debouches on to the Maritime Plain which separates the hills from the sea.

Wells are found under the same conditions in practically all the valleys of the Red Sea Hills, such as Khors, Baraka, and Arbat, while the memoirs of the Egyptian Survey[1] show that they also exist further north. Dr. Ball[2] has given us an excellent account of these Egyptian wells, from which it would appear that the valleys only differ from those of the Sudan in having a less abundant supply of water, and consequently the wells are not as frequent.

The wells of Qura, in the loop of the Nile south of Abu Hamed, are examples of another type belonging to arid regions of crystalline rock. Mr. G. S. Laird Clowes[3] describes them as situated in a small valley surrounded by granite hills. They are sunk in hard but fairly porous granite, and he supposes that the presence of water is due to the fact that Qura is the common basin into which several wadis drain, and consequently commands any rainfall that may occur over a large area. Wells of this kind are not comparable with those of the Red Sea Hills, as they depend partly on the porous nature of the decomposed rock, and thus resemble those of the areas further south, where the country is covered with Cotton Soil. I have not personally seen any wells of this type, but from accounts they appear to be of frequent occurrence.

The Maritime Plain, though a distinct area, presents conditions related to those of the Valley Fill. It is about 10 or 15 miles in width, slopes gently seawards, and, like the Valley Fill, is composed of detritus brought down from the hills. Borings have been made and show that these deposits attain a thickness of over 1000 feet. The plain is bounded along the coast by raised and modern coral reefs, broken here and there into harbours at points opposite the mouths of big rock valleys. Its surface is traversed by shallow stream-beds, and storm-water from the hills occasionally passes along them and reaches the sea. Here and among the border hills, as already noted, the rainfall occurs in winter instead of during the summer, as is the case in the rest of the Sudan. The underflow from the Valley Fill must all pass through the gravels of the Maritime Plain, and is increased as it flows towards the sea, not only by the local rainfall, but by the flood-waters from the hills as well. The water is tapped by wells at many places, where small supplies of fairly drinkable water are obtained by the natives. Such wells are found close to the sea in the neighbourhoods of Suakin and Port Sudan.

[1] *Topography and Geology of the Eastern Desert, Central Portion*, p. 251 et seq., analyses, p. 293. *Preliminary Report on the Geology of the Eastern Desert between Latitudes 22° and 25° N.*, pp. 15–16.

[2] *Cairo Scientific Journal*, 1908, vol. ii, p. 237.

[3] *Cairo Scientific Journal* (Survey Notes), 1907, vol. i, p. 350.

(*To be concluded in our next Number.*)

V.—The Loop of *Dielasma*.

By D. M. S. Watson, B.Sc., Beyer Fellow in the Geological Department of the Victoria University of Manchester.

ONE of the most important investigations carried through by the late C. E. Beecher was concerned with the development of the loop in an American species of *Dielasma*, *D. turgidum*, from the St. Louis group of the Lower Carboniferous of Kentucky.

Beecher showed that the loop in early stages was similar to that observed in the adult individuals of the genus *Centronella*, consisting of two simple short brachial processes united at their expanded anterior ends. This development is of much importance from a phylogenetic standpoint, suggesting as it does the development of the Terebratulids and Helicopegmata from forms like the Rhynchonellids and Pentamerids.

So far as I know, it has not yet been confirmed by observations on other species, so that I am glad to be able to describe some similar stages in *Dielasma hastata* from the uppermost Carboniferous Limestone of Castleton, Derbyshire, and *D. elongata* from the Middle Zechstein of Posneck, in Thuringia. These last specimens belong to the Manchester Museum, and were collected and determined by Geinitz. The loops in these specimens were developed by the method invented by the Rev. N. Glass, which I found to be easily applied even to quite small shells.

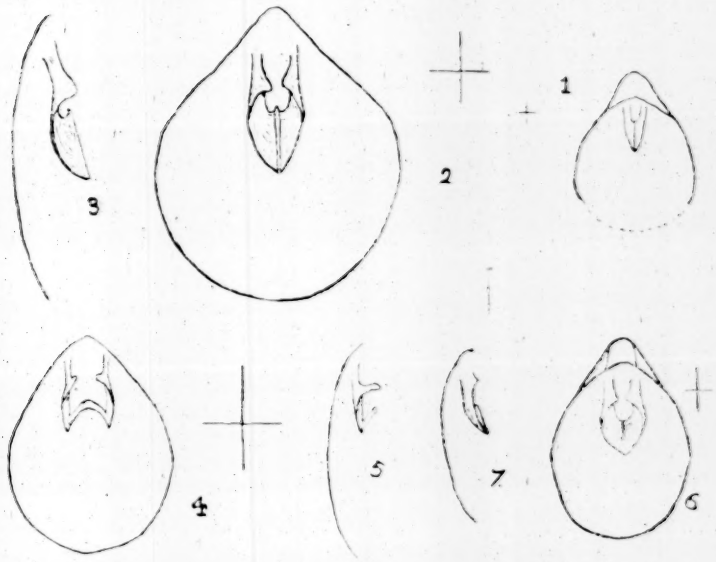
D. hastata (Sow.).

An example 4 mm. long shows a very small typically centronellid loop, about 1·5 mm. long and under 1 mm. wide. The anterior end of the brachial processes are not very much expanded in this specimen. A specimen 10 mm. long shows a loop remarkable for the extraordinary resemblance it presents to the adult *Centronella* loop. In this case the anterior ends of the brachial processes are expanded, and unite to form a strong ridge on the ventral side, which ends both anteriorly and posteriorly in a point. The jugal processes are quite distinct. The whole arrangement of the loop in this example will be easily understood from Figs. 2 and 3. An individual, 15 mm. long and 12 mm. wide, shows a typical *Dielasma* loop with ascending and descending branches.

D. elongata (v. Sch.).

An example of this species 6 mm. long by 5 mm. wide shows a loop very closely resembling that of the *D. hastata* 10 mm. long. It is drawn as Figs. 6 and 7. Three specimens of *D. sacculus vel vesiculosa* under 10 mm. in length showed the adult loop.

Although these observations are very incomplete, it being not easy to get small shells in suitable condition for development, I think they are worth publishing as affording corroborative evidence of the type of development found in the American species.



Explanation of Figures.

1. A specimen of *D. hastata* 4 mm. long, showing the loop viewed from the dorsal side. × 6.
2. A specimen of *D. hastata* 10 mm. long, showing the loop looked at from the ventral side. × 4.
3. The same specimen as that shown in Fig. 2 seen from the side.
4. A specimen of *D. hastata* 15 mm. long, seen from the ventral side. × 2.
5. The specimen shown in Fig. 4 seen from the side.
6. The loop of a specimen of *D. elongata* 6 mm. long, seen from the ventral side. × 4.
7. The specimen shown in Fig. 6 seen from the side.

NOTICES OF MEMOIRS.

On the Nomenclature of the Palæozoic Formations of Sweden.

By J. C. Moberg.

[Translated from the *Geologiska Foreningens i Stockholm Förhandlingar*, 1908, Band xxx, p. 343.]

"Das Uebergangsgebirge" (Transition rocks), or the oldest but one of the four main groups in Werner's geological scheme, corresponded, as we know, to what we now call the 'Palæozoic'. By and by it was divided up into various systems or periods, but long before that time Werner's scheme had obtained a footing in Sweden, and Swedish geologists, in referring to the Palæozoic formations of the country, used such terms as the Swedish equivalent for 'Transition rocks', 'formatio transitionis', etc. Such was the

case, for instance, in Hisinger's *Mineralogical Geography* of 1808, in Wahlenberg's book on the Formation of the Floor of Sweden (1818), and in Dalman's *Palæaderna* (1827), while in 1823 S. Nilsson, in dealing with the geology of Scania, speaks of the 'transition district' of Scania. As late as 1821 Angelin makes use of the heading "Crustacea formationis transitionis" on the title-page of his *Palæontologia Suecica*, and even in 1884 Nathorst, dealing with the geology of South Sweden, tried to reintroduce the appellation 'transition system' as a collective name for the Palæozoic strata of Sweden.

Already in 1834 and 1835 Murchison and Sedgwick had proposed the appellations Silurian and Cambrian for the formations which in England come between the Old Red Sandstone and the primary rocks, i.e. for strata which exactly correspond to the Palæozoic formations of Sweden. For reasons that I will enlarge on later there arose, practically at once, dispute as to where the line should be drawn between Cambrian and Silurian, or, in other words, about the comprehensiveness of these systems in their relation to one another. During the controversies that were consequently raised there poured in from various quarters and to various ends new proposals for the nomenclature of the strata in question. A number of these may be specially named here, since they exercised a more or less considerable influence on the nomenclature used in Sweden.

As far as America is concerned, Emmons formulated his 'Taconic System' in 1848; this, so far as it can really be considered in any way uniform, may be said to correspond roughly to the lower series of Sedgwick's Cambrian. Of more radical importance, however, was Barrande's contribution to the question. In 1846 he proposed the conception of 'Primordial Fauna', i.e. a fauna embracing the oldest known organisms and especially characterized by trilobites with long thorax and small (consisting of few segments) pygidium. Upon this followed, in their proper turns, the second and the third (Silurian) faunas. While in England it was considered adequate to divide the sedimentary rocks in question into only two systems, Barrande divided them into three sections, which proposal—especially since, following this primordial fauna, analogues to Sedgwick's Lower Cambrian could be pointed out in countries widely separated—gradually gained ground, so that in 1878 Barrande, at the International Geological Congress in Paris, called attention to the fact that Murchison himself, in the last edition of his *Silúria*, had made use of a similar terminology, in that he divided his Silurian into Primordial, Lower, and Upper Silurian.

It is clear that the Swedish geologists had, of necessity, to take up a position in reference to this question of nomenclature. But the choice, unless made haphazard, was no easy one. For in this case it is not a question of paying exclusive regard to the priority of the various appellations; it is also of importance, among other things, to investigate whether the terms proposed have a carefully fixed range, and in what measure a certain classification can be said to be suitable for giving us a clear and faithful picture of nature.

Even if the appellations that have come into use for the Palæozoic

formations of Sweden vary with different writers, by degrees the three-fold division introduced by Barrande seems to have gained universal approval. It may not be out of place here, as throwing light on the circumstances, to give a few examples of the nomenclature used by various Swedish authors after that time.

While Lindström in his *Elements of Geology* (2nd ed., 1859)—a work based on Lyell's *Elements and Principles of Geology* and other works—divides the Palæozoic formations of Sweden into Upper Silurian (= Gothland and Klinta-formation) and Lower Silurian, in which latter was also included the lowest sandstone of the Vestrogothian rocks, later on he made use of the terminology Cambrian, Lower and Upper Silurian, as for instance in his *List of the Fossil Faunas of Sweden*, i (1888).

Angelin, in his geological map of Scania with letterpress, of which two sheets were already printed in 1862, though they only appeared posthumously in 1877, gives the strata in question the common appellation "Silurian, or Older Transition Formations", remarking at the same time that the name 'Silurian System' is not used by anyone in its original sense, and also that, if we pay attention to priority, it would be more correct to use the terms Taconian, Cambrian (or Cumbrian), and Silurian for Barrande's "faune primordiale, faune seconde, and faune troisième".

In Torell's contributions to the petrology and palæontology of the Sparagmite formation he used the name Cambrian or Taconic System for Angelin's regions I–III, the next overlying strata being the Lower Silurian System; and Linnarsson, who in his earlier works (1868–9) simply comprises all the strata in question as Silurian, in all subsequent works calls Angelin's regions I–III Cambrian, IV–VII Lower Silurian, and VIII Upper Silurian.

That Nathorst, who, when he began to occupy himself with the formations we are speaking of, called those strata which include the primordial fauna 'Cambrian', and afterwards tried to introduce the term 'transition system' for the three groups of the 'Cambrian-Silurian' (Cambrian, Lower and Upper Silurian), has already been referred to above. In this place we need merely add, that the proposal in question evidently owed its origin to a desire to accentuate the necessity of introducing a collective name.

In 1880 Tullberg speaks of the Cambrian and Lower Silurian strata at Kiviks-Esperöd and Röstånga, whereas in 1882, in his work on the graptolites of Scania, he divides the Silurian formations into Primordial Silurian, Lower Silurian, and Upper Silurian, thus entirely avoiding the use of the term Cambrian.

Latterly, however, the Swedish geologists have as good as unanimously accepted the division of the Swedish Palæozoic formations into the three groups or systems Cambrian, Lower Silurian, and Upper Silurian; thus, for instance, Törnqvist (1889) in *Some Remarks on the Cambrian and Silurian Corology of Western Europe*, Holm (1901) in *Kinnekulle*, and Wiman (1899) in *Eine untersilurische Litoralfacies bei Locknesjon in Jemtland*..

Nevertheless, the name 'Silurian' has at the same time often been employed as a collective name for *all* the formations in question,

viz. by Wiman (1893) in *Über die Silurformation in Jemtland* and by Högbom (1906) in *Norrland*. The appellation Cambro-Silurian or Cambrian-Silurian formations seems, however, to be at least as common (as a collective appellation) as the name Silurian. In this case, then, the terminology has not even yet become properly established.

As far back as 1879 it was proposed by Lapworth ("On the Tripartite Classification of the Lower Palæozoic Rocks": Geol. Mag., Dec. II, Vol. VI) to change the name Lower and Upper Silurian into Ordovician (Ordovian) and Silurian, a proposal that gradually gained ground, and has of late years obtained some footing in Sweden. In 1901 Törnqvist (*Researches into the Graptolites of the Lower Zones of the Scanian and Vestrogothian Phyllo-Tetragraptus Beds*, i) used the divisions Cambrian, Ordovician, and Silurian. In 1906 he lays stress on the fact that he has definitely abandoned the older nomenclature Cambrian, Lower and Upper Silurian (*Some Remarks on the Ordovician System in Skåne*). As these works of Törnqvist's were written in English, and thus were specially addressed to the English public, he possibly attracted less attention to his new terminology from Swedish readers; that, at least, holds good as far as we are concerned. It was also with much hesitation that the writer of these lines, in a paper on the *Dicellograptus* schists of Scania (1907), and so to speak tentatively, exchanged the term Lower Silurian for Ordovician: in our opinion the suitability of the exchange from more than one point of view was not decisive. The new appellation was especially inconvenient in that it did not lend itself to the formation of compound words. Our first impression was that this difficulty might be removed by using the term Ordovian, sometimes used by Lapworth instead of Ordovician. This would have permitted such Swedish compounds as "ordovsystem, ordovfossil", etc. But, as this could evidently only be adopted if the termination *-ician* did not include any part of the stem of the word, we asked the advice of Nils Flensburg, the Professor of Comparative Philology at the University of Lund, from whom we received the following elucidation: The name Ordovices, which is met with in Tacitus (*Agricola*, ch. xviii, and *Annales*, book xii, ch. xxxiii), is made up of the stem *ordo* (or, in Old Cymric, *ord*), meaning 'hammer', and the verbal root *vik*, meaning 'to fight'. Ordovices consequently means 'hammer-fighters', and as the *vik* in it represents an independent link the form *ordov* is of course unallowable. Therefore we must write Ordovician, in which case we could also make use of such compounds as "ordoviklager, ordovikfossil", etc. So much for the purely linguistic point of view.

It is all very well that we should, by introducing the aforesaid denomination, attain to a greater uniformity with the terminology that seems to be naturalizing itself more and more abroad, especially in England and North America. But it would be better, instead of submitting our terminology to this kind of patchwork, once for all to subject this terminology in its entirety to a revision, especially as the moment for this can be said to be at hand. It is not our intention to introduce any innovations; it is merely a question of making a choice

from the older terminology, at once consistent with what is *fair* and *suited to the circumstances* in general.

In the first place we must set down that in proportion as the geological researches into our Palæozoic formations have advanced the old conviction that the latter in our country form a connected whole, the various parts of which are not divided by sharp limits, has become a certainty. However, for faunistic reasons it seems advisable to divide the formations in question into *three* groups, in the main corresponding to Barrande's three Silurian faunas. It is no less for the formations considered as a whole than for the various groups that we must establish appellations.

Before entering upon this we must touch, however briefly, upon a very debated question of priority, viz. the name Silurian or Cambrian. In our opinion it is the more bootless to enter into details, as no one is likely to assert that either Murchison or Sedgwick were really fully cognizant of what it was that they stamped with the respective names. That any dispute about the line between the different systems could arise at all is due, of course, to the fact that the authors themselves did not recognize with certainty coeval formations where these in any degree showed varying development. That Murchison's Caradoc was the same as Sedgwick's Bala, was a point on which both were equally in the dark, even if Sedgwick, as it soon appeared, saw that this was the case, at least as far as certain strata were concerned. That Murchison's stratigraphical mistakes, which considerably increased the chaos, did not bring him great distinction, goes without saying, but on the whole we must not forget that palæontological science at that time, when, for instance, the graptolites and their stratigraphical significance were still practically unknown, was insufficient to determine with certainty the stratigraphical succession when the strata were not in a relatively undisturbed position. That both Murchison and Sedgwick added so much to our knowledge of these older Palæozoic strata, that the names given by them must by no means be condemned by reason of the flaws which were inherent in them, and which, we may say, were bound to exist in them, is beyond all doubt. But the manner in which these names should be used, or, in other words, the establishment of the range of their meaning, must concern a period which will have made a real limitation of the idea possible.

To return to the question of what appellations we are to select, our first business is to see what names can be used as a *collective appellation* for these formations. Among the likeliest of these we may mention especially Transition System, Cambro-Silurian, and Silurian. Of these, for reasons we need not repeat here, Transition System is very unsuitable. The same is true of Cambro-Silurian, especially as Sedgwick himself proposed this name in 1843 for all strata from the Bala, inclusive, to the base of the Wenlock, a proposal which, however, he afterwards (1854) withdrew. On the other hand, the name Silurian seems to be quite suitable, not only because the range of the word corresponds with Murchison's latest claims, but because it has often been used, as we pointed out above, as a collective name. *But if it is to be used as such it must, of course, not be admitted as a group name.* Since, for obvious reasons, we retain the names

Cambrian and Ordovician [1] for the two lower groups, it remains for us to choose another name for what is otherwise called Upper Silurian or Silurian.

In 1900 de Lapparent, in his *Traité de Géologie*, proposed for this group the name 'Gothlandien'. And we think there is every reason to accept this proposal. The sedimentary rocks which are here in question are completely represented [2] in Gothland, and no other strata occur among the rocks there. As Cambrian and Ordovician have been named from tribes, we should, perhaps, in case we had to choose the name, take one that would recall to us the Gutar, the Gothland settlers—for instance, Gutnium or Gutnian; but such an emendation of de Lapparent's appellation would be looked upon as exaggerated purism. Already in Angelin's General Map of Scania, there is a mention of a "Fifth or Gothland Group" as being about synonymous with what has latterly been called Upper Silurian. Even if we wish to see in this a pronouncement in favour of the nomenclature here recommended we must point out that as an adjective to the proposed name Gotlandian we ought to adopt a new term, 'Gotlandisk' (Gothlandic), since the Sw. 'gotländsk' (or the representative prefix form, 'Gotland's–') should be reserved for cases where there is some reference to the Island of Gothland or its belongings.

Even provided the name Gotlandian should not readily gain the approbation of strangers—we know how long it was before Lapworth's Ordovician made its way—it can safely be used in our country without danger of being either *not understood or misunderstood*.

This, then, is the nomenclature we propose: *Silurian*, with the three series, *Cambrian*, *Ordovician*, *Gothlandian*. This nomenclature fully takes into consideration the excellent methods in disentangling the formations in question that we owe to Murchison, Sedgwick, Barrande, and Lapworth. And it can scarcely be considered presumptuous if the Silurian geologists of Sweden, in generally adopting de Lapparent's appellation, Gotlandian, recognize in some measure what we hold to be a noticeable contribution made by them and their predecessors to the Silurian division.[2]

If anyone should possess world-embracing views it is the geologist; but, as a matter of fact, even his point of view is not a little influenced by his nearest surroundings—his own country and the prevalent opinions in it. A word or two supplementary to what has been said above seems to me, therefore, to be appropriate on this occasion, since I am now especially addressing English readers.

[1] As it is quite superfluous to repeat here the reasons stated by Lapworth (see op. cit.), in our opinion most satisfactorily, for his proposed name, Ordovician, we will only point out that this name, apart from the fact that its meaning offers a way out of a difficulty in nomenclature acceptable to the various English schools, is also made necessary, so to speak, for us, since on the one hand we wish to retain the name Cambrian, but on the other hand wish to use the name Silurian exclusively as a collective appellation.

[2] However, J. Kiaer, in his *Das Obersilur im Kristianiagebiete*, which has just appeared, expresses the opinion that the lowest strata in Gothland correspond to the *uppermost* part of Llandovery; the lower part of the latter is therefore inaccessible in Gothland. Moreover, he questions whether there is anything there to correspond to the most recent Ludlow strata.

As far as I have been able to discover, the majority of the English geologists at the present time wish the term Ordovician to be generally adopted. And so do I. We are also of one mind that, if the term Lower Silurian is to be rejected, the term Upper Silurian must also be given up. But when the proposal is made to substitute for the latter the term 'Silurian' simply, then I think a false move has been taken, which may lead to confusion not only abroad but also in England. Even if Murchison's term, Silurian, was originally applied to only the upper part of the formations in question, it must not be forgotten that it was created earlier than the term Cambrian, and that also Llandeilo was included in it. Murchison's term, Silurian, has consequently never coincided with what would now be called by that name. And lastly, as we know, he let the name embrace all the strata from the base of the Cambrian up to the base of the Devonian. In this comprehensiveness the name Silurian, especially through Barrande's influence, has also come to be used throughout the world.

To use the name Silurian in the significance that English geologists have of late attempted is, as I have shown above, not justified, as well as very misleading. To discard it entirely is quite unfeasible; not only would it be an act of great injustice towards the renowned author of the Silurian System, but it would be an injustice that would assuredly bring its own punishment.

Since, then, the term Silurian *must* be used, it seems to me that nothing else is possible but to take it in the sense Murchison ultimately gave it, which, through Barrande's influence, has won favour everywhere. If the name Ordovician is introduced, the name Silurian, as far as I can see, must be used as a collective name, and the so-called Upper Silurian receive a fresh name. And as such, de Lapparent's 'Gothlandien' (Gotlandium) would certainly be suitable.

REVIEWS.

I.—Rock Salt: its Origin, Geological Occurrences, and Economic Importance in the State of Louisiana; together with Brief Notes and References to all known Salt Deposits and Industries of the World. By G. D. Harris, assisted by C. J. Maury and L. Reinecke. Bulletin No. 7 of the Geological Survey of Louisiana, 1908. pp. 259, with 21 text-figures and 48 plates of maps, sections, and views.

THE 'salines' of North Louisiana were known to the Indians before the advent of the white man, and they used to resort to those places to obtain their salt. The position of the 'salines' is indicated by the 'licks', where vegetation is prevented from growing, over patches several yards square, by the licking of the ground by cattle.[1] Their presence is further indicated by brine-springs which issue along the beds of streams, and by the sinking of wells. Brine

[1] The "Big Bone Lick", Kentucky, and others of a similar kind were well known to the early geologists by the discovery of abundance of remains of the *Mastodon* and other extinct mammals who came down to lick the salt in prehistoric times. Many arrow-heads of stone have been found, showing that the Indians also frequented these salines, probably to shoot big game which came there for salt as well as themselves.

has been obtained from the springs by sinking vertical hollow logs over their sources along the stream-bed and pumping the salt water. During the past three years it has been proved by boring that vast masses of rock-salt occur beneath some, if not all, of the salines, and in various parts of the State. At one spot in South Louisiana the drill entered rock-salt at a depth of 334 feet and continued in it without change to a depth of 2090 feet; in another, a thickness of 2263 feet of salt was passed through, and after a further depth of non-saliferous strata had been passed through, salt was again encountered of unknown thickness. At this latter locality, Petite Anse, the amount of salt present is estimated at about 2,000,000,000 tons; and, as the author remarks, "no one can claim to have but the faintest idea of the true value of the huge masses of pure rock-salt stored away in the 'islands' and salines of Louisiana." The term 'island' is here applied to the mounds or domes beneath which the salt is obtained by mining.

The salt occurs in the Eocene and Quaternary strata, which consist of clays, loams, sands, and gravels, with occasional limestones and lignites. The details vary much, and in one locality there was found, at successive horizons, limestone, gypsum, occasional oil and gas, and finally below, with unknown thickness, rock-salt. All the mounds and salines thus far prospected have shown the existence, singly or in association, of salt, gypsum, sulphur, dolomite, petroleum, hot sulphurous and saline waters, etc.

The origin of the domes was attributed by Hager to upthrust of faulted masses of Cretaceous and Carboniferous rocks beneath the yielding Tertiary deposits, in which the faulting of the strata below was replaced by simple anticlinal folding. The pressure of gas, oil, water, and of hypothetic igneous plugs have also been referred to as agents likely to account for the phenomena. The present author and his associates attribute the uplifting to the power of growing crystals. They admit that they have not at present determined the power of growing crystals, but they infer that it will be found to be of the same order of magnitude as the resistance which the crystals offer to crushing stresses. A 4 inch cube of crystallized salt, which had been mined with dynamite, and was apparently more or less inclined to crumble, showed no sign of crushing when put under a pressure of 50,000 lb., the limit of the small hydraulic press used. Further experiments are, however, desirable. The very restricted areas occupied by the salt-masses compared with their thickness is a remarkable feature. With regard to the age of the domes the author considers that they were formed whenever conditions were favourable, and that the various mineral deposits of salt, oil, sulphur, gypsum, etc., though often flowing into Tertiary or Quaternary reservoirs, originated in beds belonging to earlier periods of the earth's history.

A valuable record of salt deposits and brine springs in other parts of the world occupies about two-thirds of this report; and it is remarked that while in France and Germany there are works that cover somewhat the same ground, there is no recent English work on the subject.

II.—The Eruption of Vesuvius in April, 1906. By H. J. Johnston-Lavis, M.D., etc. Reprinted from the Scientific Transactions of the Royal Dublin Society, vol. ix, pt. viii, January, 1909.

THE 1906 eruption of Vesuvius attracted a great deal of attention, as it presented many novel features of interest, and a large number of reports have been written on it by the members of that band of scientific men which gathered in Naples in the spring of that year. Its most important characteristics are now well known, but there was certainly room for an account of it from the pen of Professor Johnston-Lavis. In this paper he gives a brief account of the activity of the volcano up to the end of April, 1906, with a description of the petrographical character of the lava and the ashes emitted. This leads to a consideration of the sequence of volcanic processes within the crater, a subject on which the author has already formulated his views on several occasions. Great changes took place in the configuration of the cone of Vesuvius, and, when the dust-cloud of the eruption cleared away, a remarkable series of deep radial furrows or 'basancos' became visible, traversing the ash-covered slopes which descend from the crater. These were produced by small landslips of the fine dry ash, which initiated avalanches of volcanic sand and stones. As they flowed downward they carved deep narrow valleys, not only in the new ash but also in the older tuffs. Some beautiful views of these are given, and with a couple of excellent maps they add considerably to the interest of the paper.

III.—International Geological Congress: Eleventh Session, to be held in Stockholm, 1910.

At the tenth meeting of the International Geological Congress in Mexico, 1906, the Swedish geologists invited the Congress to hold its next session in Stockholm, an invitation that was unanimously accepted. In view of the extensive preliminary work occasioned by the projected excursions, a wish was expressed by the Swedes that the meeting in question, which should really have taken place in three years' time, might be postponed until 1910. The decision was left to the Swedish geologists, and subsequently 1910 was fixed upon by the Swedish Organizing Convocation for the meeting in Stockholm.

A general meeting of the Swedish geologists was held in Stockholm on March 5, 1907, for the purposes of drawing up a general programme for the work of organization and instructing the Executive Committee. On the retirement of the former Director of the Geological Survey of Sweden, Professor A. E. Törnebohm, his place as President of the Committee was taken by Professor G. de Geer; the Treasurer of the Committee is Professor H. Bäckström; while Professor J. G. Andersson, the present Director of the Geological Survey of Sweden, officiates as General Secretary.

The Swedish Executive Committee considers it advisable that *preference* should be given to the discussion of such questions at the meeting of the Congress in Stockholm as the actual geological

phenomena of Sweden or of the polar regions can throw light upon. Particular attention should thus be devoted to the following domains of geological science:—

1. The Geology of Archæan Rocks.
2. The Geology of the Quaternary Period (especially climatic changes in late and post-Glacial times).
3. The Geology of the Polar Regions.
4. Applied Geology (especially the extent and distribution of the supplies of iron-ore in the world).

Numerous excursions have been planned in connection with the Congress.

Before the Meeting.

1. Northern Sweden (Norrland).
   - (*a*) Large overthrusts, post-Archæan eruptive rocks, etc. 20 days.
   - (*b*) The ore-fields of Cellivaro and Kirunavara. 10 days.
   - (*c*) Quaternary formations in Jämtland. 10 days.
   - (*d*) Quaternary formations in Norrbotten. 10 days.
2. Spitzbergen. About 3 weeks.
3. Peat-beds in Central Sweden. 6 days.

During the Meeting.

Several one-day excursions.

After the Meeting.

1. Five simultaneous excursions in Southern Sweden, excepting Scania. 12 days.
   - (*a*) Archæan rocks.
   - (*b*) Cambrian-Silurian beds.
   - (*c*) Quaternary deposits.
   - (*d*) Ores.
   - (*e*) General geology.
2. (To follow 1.) Three simultaneous excursions in Scania. 7 days.
   - (*a*) Cambrian-Silurian beds.
   - (*b*) Mesozoic beds.
   - (*c*) Quaternary beds.

The first excursions (to Spitzbergen and Norrland) begin about July 25, the meeting of the Congress takes place about August 18–26, and the last excursions (in Scania) end in the middle of September.

This programme is subject to alterations; the present scheme is provisional.

All correspondence having to do with the coming Congress should be addressed to the General Secretary, Professor J. G. Andersson, Stockholm (3), Sweden.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—*April* 7, 1909.—Professor W. J. Sollas, LL.D., Sc.D., F.R.S., President, and afterwards H. W. Monckton, Treas.L.S., Vice-President, in the Chair.

The President announced that the Daniel-Pidgeon Fund for 1909 had been awarded to Mr. A. M. Finlayson, who proposes to undertake researches on the Genesis of the Sulphidic Ores.

The following communications were read:—

1. "On Overthrusts at Tintagel (North Cornwall)."[1] By Henry Dewey, F.G.S.

In this paper the author deals with the geological structure of the Tintagel area. After brief reference to the stratigraphy north of Bodmin Moor, mention is made of the apparent difference in order of superposition of the beds near Tintagel.

The several types into which the Upper Devonian rocks are divided are next described. The beds in descending order are—

(6) Tredorn Phyllites.
(5) Trambley Cove Gritty Slates.
(4) Volcanic Series.
(3) Barras Nose Beds.
(2) Woolgarden Phyllites.
(1) Delabole Slates.

The above order is preserved for many miles, between the Boscastle coast and Lewannick on the eastern side of Bodmin Moor. A change of strike at Tintagel reveals the anticlinal structure of the district. To the south of the nose of this great fold minor folds cross the strike. These folds increase westwards until they are replaced by overthrusts. Four sections from east to west show the increased folding and overthrusting towards the northern part of the area.

The paper concludes with a reference to the age of the folding.

2. "The Lahat 'Pipe': a Description of a Tin-Ore Deposit in Perak (Federated Malay States)." By John Brooke Scrivenor, M.A., F.G.S. (Geologist to the Federated Malay States Government).

Large quantities of tin-ore have been obtained during recent years in the Kinta district of Perak, principally from detrital deposits, but also in some cases from the limestone which forms the floor of the Kinta Valley. From 1903 till 1907 the Société des Étains de Kinta secured over 1000 tons of dressed tin-ore from a peculiar deposit which had the form of a pipe in the limestone, measuring only 7 by 2 feet at the surface, but widening when followed downwards. It was worked to a depth of 314 feet. The veinstone was a deep red mixture of calcite and iron-oxide, with some quartz, chalybite, and chalcopyrite, but no tourmaline was found in it. In this the cassiterite occurred in irregular pieces and broken fragments, some of which consisted of radiating needles.

In Kinta the tin-ores occur in the limestone in two different ways—(1) As lodes or veins with fresh sulphides but not iron-oxides. The tin-oxide crystals have a definite arrangement. (2) As transformed masses deposited in fissures. The cassiterite is in rounded grains, and quartz, tourmaline, and other minerals, also well rounded, accompany it. For a long time it has been doubtful to which of these classes the Lahat pipe should be assigned, as it presents some features of each class. Recently, however, specimens have been obtained showing veins of arsenopyrite and cassiterite in limestone, and from these the author concludes that the Lahat pipe was originally a vein or lode deposit in the limestone, which subsequently afforded a course for surface waters; these dissolved away the calcite and

[1] Communicated by permission of the Director of H.M. Geological Survey.

oxidized the sulphides, caves being formed into which the insoluble ores were carried by the water. Finally, the brecciated mass was recemented. Some foreign material has been introduced, but the bulk of the contents of the pipe is of local origin and consequently not rounded by transport. In other words, the Lahat pipe is a lode deposit which has been converted into a detrital deposit *in situ*.

3. "On the Sculptures of the Chalk Downs in Kent, Surrey, and Sussex." By George Clinch, F.G.S., F.S.A. Scot.

The author classifies the various forms of sculpture of the Chalk Downs under three heads, namely, (1) dry valleys of simple form, (2) dry valleys of complex form, and (3) wet valleys. He draws attention to the relatively small catchment areas of the dry valleys, and to the large number of tributary valleys found in some districts, two points which he considers have not received hitherto entirely satisfactory explanation.

While accepting the view that frozen conditions in former times altered the drainage system of the Chalk, he argues that the most potent excavating force was the frost itself acting on Chalk saturated or highly charged with water. He propounds a theory to account for (1) the great size and breadth of the valleys in relation to their catchment basins; (2) the ramifications of some of the valley systems; and (3) the remarkable fact that many dry valleys die out just before the crest of the Chalk Downs is reached.

April 28, 1909.—Professor W. J. Sollas, LL.D., Sc.D., F.R.S., President, and afterwards Professor W. W. Watts, Sc.D., F.R.S., Vice-President, in the Chair.

The following communications were read:—

1. "The Boulders of the Cambridge Drift." By Robert Heron Rastall, M.A., F.G.S., and J. Romanes, B.A.

For several years past a large number of boulders have been collected from the glacial drifts of Cambridgeshire, and from the post-glacial gravels which have been derived from the drifts. These specimens have been classified geographically and then subjected to a careful petrological examination, with a view to the determination of their origin. Some special collections from Hitchin and Bedford have also been included for comparison. Rocks of Scandinavian origin, and especially those of the Christiania province, are abundant throughout the whole area: such well-known types as rhomb-porphyry and nordmarkite are common. Rocks from the Cheviots and Central Scotland are more abundant than was formerly believed, and specimens have also been identified from the Old Red Sandstone conglomerates of Forfarshire and from Buchan Ness, Aberdeenshire. Lake District rocks probably also occur in small quantity. Much of the Chalk and flints appear to be of northern origin. It is concluded that an older Boulder-clay, containing foreign erratics, the equivalent of the Cromer Till, once extended over the whole district, but was subsequently incorporated with the Great Chalky Boulder-clay. The Scandinavian ice advanced from the direction of the Wash, bringing with it Red Chalk and bored Gryphæas from the bed of the North Sea, and carrying them as far west as Bedford. Rocks from the north of the

British Isles become progressively scarcer from west to east, and the distinctive types are absent to the east of Cambridge. They appear to have been brought by an ice-stream coming from a northerly direction, which probably to a certain extent replaced the Scandinavian ice towards the east.

2. "The Nephrite and Magnesian Rocks of the South Island of New Zealand." By A. M. Finlayson, M.Sc. (Communicated by Professor W. W. Watts, Sc.D., F.R.S., V.P.G.S.)

The magnesian rocks described in this paper are a disconnected series of intrusive peridotites, forming a more or less defined belt along the western portion of the South Island, parallel to the trend of the Island and to the structural and geographic axes of the main Alpine range. The course taken by these rocks apparently follows one of the main Pacific trend lines, the nature of which will be more fully understood with the further elucidation of the structural geology of the region. The rocks are intrusive into sedimentary strata of ages varying from Ordovician to Jura-Trias, and, as far as can yet be determined, all the exposures appear to be of approximately contemporaneous origin.

One of the most interesting groups is at the Dun Mountain, Nelson, where the original dunite of Hochstetter occurs, associated with magmatic segregations of chromite, bands of pyroxenite, serpentine rock, and a variety of rock types of contact-metamorphic origin bordering on the Triassic Limestone which is intruded by these rocks. The rocks of the contact zone include grossularite diallage rock, serpentine amphibole rock, and epidote rock.

In Westland, near Hokitika, the rocks occur as a series of sills which are of two varieties—massive or foliated serpentine rock, and serpentine-talc-carbonate rock. The former are often seen to be of the variety antigorite, with typical thorn structure, and some specimens show the process of serpentinization of augite lately described by Professor Bonney from this region. The serpentine-talc-carbonate rocks are the matrix of the New Zealand nephrite or greenstone, which also occurs as boulders in the adjacent river valleys and glacial drifts.

At Anita Bay, Milford Sound, occur a dunite with marked cataclastic structure, a hartzbergite in which the enstatite is often completely altered to magnesite, and a foliated talcose rock containing stringers and veins of the tough and highly translucent bowenite—the tangiwhai or 'tear-drop' of the Maori. Chemical and microscopic examination leads to the conclusion that the bowenite has here been formed by deep-seated metamorphism of a talc rock, with the development of serpentine and magnesite, the former being transformed into the tough fine-grained bowenite by dynamic forces of considerable intensity.

A notable feature of all the rocks of this peridotite belt is the close association of the most highly serpentinized varieties with evidences of former hydrothermal action accompanying the intrusions. The widespread serpentinization seen in many cases seems to have been largely effected or at least initiated by hydrothermal action.

The nephrite, or Pounamu of the Maori, occurs as nodules and veins in the serpentine-carbonate and talc-carbonate rocks of the Griffin Range, Westland. Its commonest colour is a deep translucent green, but many different shades occur, depending on the percentage of ferrous silicate, on the presence or absence of flaws and cracks, and on included or infiltrated oxides of iron. Some of the dark-green nephrites are among the finest specimens of this mineral in existence. A pale whitish-green variety is also occasionally found. It is, however, rather opaque and never approaches in sheen the famous pale 'jades' of Turkestan.

Microscopically, the nephrite shows a foliated or confused aggregate of very fine fibres, the denseness of the fibrous mass being evidently the cause of its hardness.

It appears to have been originally formed by several modes: (1) by contact-action between peridotites and lime-bearing rocks, (2) by uralitization of pyroxenes, (3) by direct transformation of olivine into finely fibrous amphibole, (4) by deep-seated metamorphism of serpentine-talc-carbonate rock or its prototype.

These modes all suffice to produce the necessary chemical changes, but the transformation to true nephrite has involved, in addition, intense rock-pressure and movement. Thus has finally resulted the dense foliated or felted aggregate of fibres which characterizes nephrite.

CORRESPONDENCE.

CHRYSOLITE, CHRYSOTILE, AND KARYSTIOLITE.

Sir,—May I call the attention of your readers to the inconvenience caused by the similarity between the terms *chrysolite*, a synonym of olivine adopted by Dana as the name of the species, and *chrysotile*, given by Kobell (Jahrb. prakt. Chem., 1843, vol. xxx, p. 469) to the fibrous variety of serpentine. Twice within the last twelve months I have had occasion to use the term 'chrysotile' in publications (Proc. Geol. Assoc., 1908, vol. xx, p. 462; Bull. Imp. Inst., 1908, vol. vi, p. 394), and on both occasions it has been transformed into 'chrysolite'. In the case of the article in the Bulletin I was able to verify the fact that the right word appeared not only in the manuscript but in three successive proofs, and that it was only at the last moment that it was corrected (!) in every place where it occurred by a reader for the press. In the other case the proofs were not available for reference, but the manuscript was found to be correct.

The two words are a continual source of confusion to students, and I would suggest the revival in the form *karystiolite* of the original name of the mineral, *καρύστιος λίθος*, from Karystos, in Eubœa, where it was obtained (Min. Mag., 1906, vol. xiv, pp. 143–5). 'Karistia' was still in use in modern Greek in this sense towards the close of the eighteenth century (id., p. 147). The term 'marmor carystium' appears to have been applied by Pliny to serpentine rock quarried in the same locality (Nat. Hist., iv, 21, and xxxvi, 7).

John W. Evans.

Imperial Institute.
April 30, 1909.

CLIMATE AND TIME.

SIR,—The discoveries of Scott and Shackleton show that in the Antarctic, as in the Arctic, the climate is ameliorating. When Scott visited the Great Barrier in 1902 he found it had retreated many miles since the days of Ross, and Ferrar from other evidence concluded that the ice masses are gradually shrinking in size.

This raises a very interesting point concerning the theories which have been formed to account for warm and glacial periods. According to Croll's theory the cold and warm periods occurred during times of great eccentricity in the earth's orbit, and the cold and warm periods alternated between the north and the south polar areas owing to the precession of the equinoxes. In other words, the climatic changes taking place must be of opposite character in the northern and southern hemispheres, whereas the facts appear to be, as already stated, that the climate is now ameliorating in both hemispheres. Moreover, the great number of cold and warm periods Croll's theory requires seems to me to be greater than is warranted by the geological evidence available.

It is admitted that the total amount of heat received by the earth from the sun each year is only very slightly affected by changes in the eccentricity of the earth's orbit. There is also reason to believe that the obliquity of the earth's orbit has not varied appreciably. We are, therefore, constrained at present to admit that, at least as regards recent glacial periods, the cause of the climatic changes must lie in the variable way in which the heat is received from the sun and reflected or retained during the winter and summer seasons and the indirect results thus brought about.

The essence of Croll's theory is that at times of great eccentricity there are periods during which the difference between the amount of heat received during winter and summer is very great on one hemisphere, whilst on the other hemisphere the quantities of heat received during the two seasons is more equable. When the winters are sufficiently cold the precipitation is almost wholly in the form of snow, and if the snowfall is sufficiently great the summer sun is unable to melt it; for owing to the heat being reflected from the white surface, or intercepted by fog, the part of the hemisphere concerned does not profit proportionately by being nearer to the sun. A great amount of heat is also required merely to change the ice to water.

Now I would suggest that during periods of great eccentricity, when the winter of one hemisphere is in aphelion, the collection of ice and snow is so great that the warmth of summer when the same hemisphere is in perihelion is unable to melt it except in low latitudes, and glacial periods are thus produced concurrently in both hemispheres during times of great eccentricity.

When, during periods of great eccentricity, the equinoxes are in aphelion and perihelion the conditions are also favourable for the collection of snow and ice in both polar areas; for during the time one equinox is in perihelion the equatorial region receives a great amount of heat from the sun, evaporation is promoted, and the precipitation of snow at the poles is increased. On the other hand,